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# NAVAL POSTGRADUATE SCHOOL

## Monterey, California



## THESIS

**A BUSINESS CASE FOR USING MODELING AND  
SIMULATION IN DEVELOPMENTAL TESTING**

by

Joan M. Smith

June 2001

Thesis Advisor:  
Associate Advisor:

Michael Boudreau  
C. David Brown

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**A BUSINESS CASE FOR USING MODELING AND SIMULATION IN  
DEVELOPMENTAL TESTING**

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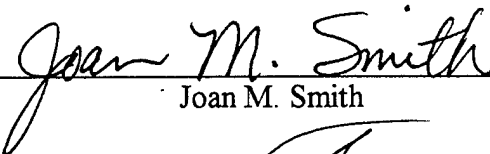
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requirements for the degree of

**MASTER OF SCIENCE IN PROGRAM MANAGEMENT**


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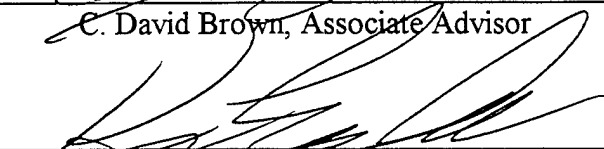
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## ABSTRACT

Modeling and Simulation (M&S) technology uses models to develop data as a basis for making managerial or technical decisions. M&S can be a valuable tool for decision-makers but it is usually under-used. The United States Army Developmental Test Command (DTC) is leveraging M&S to accomplish its missions through the Virtual Proving Ground (VPG) Program. DTC supplies a customer decision-maker, usually a Program Manager (PM), with data on the cost-effectiveness of new virtual and physical test technologies in order to plan test activities. DTC requires a methodology to develop a business plan that supports the use of M&S and to provide a cost benefit analysis of particular virtual test capabilities. DTC commissioned independent studies of past test programs to estimate the costs to achieve the same scope of testing, as tested using available virtual test techniques and as using previous, less VPG-intensive test methodologies. The studies showed that virtual testing provided significant cost benefits to each PM. An objective is to examine cost avoidance results from those studies and additional data with a methodology consistent with current cost estimation guidance to determine a return on investment relationship. This thesis will endeavor to establish an equitable methodology for accounting or realizing the direct benefits associated with using M&S in testing. The details of the steps will be developed as necessary to perform a business case analysis.

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## LIST OF ACRONYMS

ACADA	Automatic Chemical Agent Detector Alarm
ACR	Advanced Concepts and Requirements
AGMS	Air to Ground Missile System
AMSO	Army Modeling and Simulation Office
ARPA	Advanced Research Projects Agency
ATC	Aberdeen Test Center
ATEC	Army Test and Evaluation Command
ATD	Advanced Technology Demonstrations
ATFMS	Acquisition Task Force on Modeling and Simulation
BCA	Benefit Cost Analysis
BCR	Benefit Cost Ratio
CASA	Cost Analysis Strategy Tool
COTS	Commercial off the Shelf
DIS	Distributed Interactive Simulation
DoD	Department of Defense
DMSO	Defense Modeling and Simulation Office
DT	Developmental Testing
DTC	Developmental Test Command
DTS	Detector Test System
EPLRS	Enhanced Position Location Reporting System
FTB	Fly-to-Buy
GPRA	Government Performance and Results Act
HF	Hellfire
HITL	Human-in-the-Loop
HLA	High Level Architecture
HWIL	Hardware-in-the-Loop
ICAF	Industrial College of the Armed Forces
IDA	Institute for Defense Analyses
IR	InfraRed
IPT	Integrated Product Team
IRR	Internal Rate of Return
LBHF	Longbow Hellfire
LRIP	Low Rate Initial Production
M	Moving
M&S	Modeling and Simulation
NPV	Net Present Value
OMB	Office of Management and Budget
OTC	Operational Test Command
PC	Personal Computer
PIR	Post Implementation Review
PEO	Program Executive Office
PM	Program Manager

PQT	Production Qualification Test
PV	Present Value
PVT	Production Verification Test
RDA	Research, Development and Acquisition
RDEC	Research Development and Engineering Center
ROI	Return On Investment
RTTC	Redstone Technical Test Center
SIMNET	Simulation Network
STAF	Simulation Test Acceptance Facility
S	Stationary
SWIL	Software-in-the-Loop
SBA	Simulation Based Acquisition
SSP	Simulation Support Plan
TCC	Test Control Center
T&E	Test and Evaluation
TEMO	Training, Exercises and Military Operations
TIS	Test Item Stimulator
TOC	Total Ownership Cost
TRADOC	Training and Doctrine Command
TWI	Trench Warfare I
USD(A&T)	Under Secretary of Defense for Acquisition and Technology
VPG	Virtual Proving Ground
WSMR	White Sands Missile Range

# **I. INTRODUCTION**

## **A. PURPOSE**

The research area of this thesis will be Modeling and Simulation (M&S) Policy as it pertains to the economics of its application in the acquisition discipline of developmental testing.

The US Army Developmental Test Command (DTC) has the missions of developmental technical testing and safety certification of all Army materiel. A test might be a live test of physical hardware in a physical environment or a virtual test of simulated, and/or physical hardware in a simulated environment. DTC is leveraging M&S to accomplish its missions through the Virtual Proving Ground (VPG) Program. DTC supplies a customer decision-maker, usually a Program Manager (PM), with data on the cost-effectiveness of new virtual and physical test technologies. DTC requires a methodology to develop a business plan that supports the use of M&S and to capture the cost avoidance of particular virtual tests consistent with current Army cost estimation procedures. DTC commissioned independent studies of past test programs to estimate the costs to achieve the same scope of testing, as tested using available virtual test techniques and as using previous, less VPG-intensive test methodologies. The studies showed that virtual testing provided significant cost benefits to each PM. An objective is to examine cost avoidance results from those studies and additional data with a methodology consistent with current cost estimation guidance to determine a return on investment relationship.

## **B. BACKGROUND**

The earliest use of modeling can be traced back to 1867 with the Rigid Kriegspiel (War Game). M&S have been used in the design of weapon systems for many years. The testing community has been using M&S techniques for the at least the last ten years to enable testing that was previously not possible or economical. The testing community needs a consistent technique to quantify the benefit of using M&S. This benefit can then help prove that sound decisions are being made for using M&S. More particularly, the developmental test community needs a technique since they are integral part of assessing whether the performance of a weapon system is mature and ready for production. The developmental testing community is constantly working with the research and development community that is using M&S extensively. With the advent of the use of M&S as directed by Department of Defense (DoD) policy, the costs and associated benefits with the development and use of M&S techniques fit traditional cost benefit models with modification and much emphasis on indirect benefits. Commonly, the decision to employ M&S comes as a result of policy direction rather than economic benefit. There is no documented or rigorous technique to account for the benefit realized when using M&S in the developmental testing process. This thesis will endeavor to establish an equitable methodology for accounting or realizing the direct benefits associated with using M&S in testing. The details of the steps will be developed as necessary to perform a business case analysis.

While there are some common applications industry-wide, DoD is not focused on profit, but on performance and total ownership costs. The 1993 Government Performance and Results Act (GPRA) has put pressure on PMs by putting in place a

results-based management regime intended to tie funding decision directly to program performance (Laurent, 2000). The GPRA requires organizations to set outcome goals, measure their performance and report their accomplishments. These reports to be developed by PMs must be coupled with cost data and based on credible information to enable decision-makers to make funding decisions. The GPRA is going to push agencies to clarify their business lines and to collect performance and cost information. With this information, PMs will be better able to build "better business cases for maintaining current programs or moving to more effective methods for achieving results" (Laurent, 2000). A recent Industrial College of the Armed Forces (ICAF) team surveyed a large number of DoD PMs with programs in various stages of the acquisition process. The survey requested general information from the PMs regarding how they made decisions on M&S investments. In an effort to maintain balance, they also surveyed several Government contractors. Additionally, they also conducted a literature search to capture the body of knowledge in non-Government organizations related to justifying M&S investments.

The ICAF team published their efforts in the Fall 2000 issue of the Acquisition Review Quarterly. The article provides a business case framework for Program Managers (PMs) within the Department of Defense to use when determining how to apply modeling and simulation in project management (Brown, Grant, Kotchman, Reyenga, & Szanto, 2000). This thesis will build upon this framework to develop one for developmental testing. A business case analysis is a methodology to evaluate investment opportunities. M&S employ models, either statically or over time, to develop data as a basis for making managerial or technical decisions. Models are physical, mathematical

or logical representations of a system, entity, phenomenon, or process (DoD, 1997). Simulations are methods for implementing models over time. Normally, we associate simulations with a software program that implements models over time, within the context of a given scenario. Simulations permit the user to assess variables and the predictability of a single or series of outcomes.

The use of M&S is widely misunderstood within the DoD. Recent Government direction to use Simulation Based Acquisition (SBA) in DoD programs is an example of a policy with good intentions but poorly shaped execution. This edict has been met with, at best, marginal acceptance, and at worst, abject resentment. Such resentment and apprehension spring from institutionalized biases, including DoD funding procedures, that work against optimizing the potential gains of employing modeling and simulation. By far, the severest criticisms targeted at M&S center on the debate over Return on Investment (ROI). ROI is just one of many techniques for evaluating the use of M&S in a program. Ostensibly, DoD has accepted this new technology as a means of reducing costs, increasing cost avoidance and banking the residual benefits for other projects. Seldom is the PM or testing community given sufficient funds, staff, or time to investigate the potential benefits of tools or technologies such as M&S. Importantly, leadership provides little incentive to capture data, build expensive models or conduct additional analyses to transfer M&S results to other projects. Simply put, everyone is under intense pressure to complete his or her programs on or under budget and within time lines. Existing programs lack enticement to develop new models or simulation tools that may have wider application to other programs, or that will be much cheaper to

operate and sustain. With few exceptions, these occurrences were more a result of coincidence than deliberateness.

Perhaps the greatest impediment to M&S acceptance is lack of knowledge. Many people do not understand the potential benefits of this technology, or how to define needs and produce the right tools that will help the project. Unfortunately, this reticence may be reinforced by an institution which neither favors nor rewards risk takers. Sometimes, a PM may not know for certain if a major investment in M&S is warranted. If he wants to invest in the technology "just to see if there is a benefit" he faces criticism if the results are not positive. Thus, he must weigh the costs of the risk, and consequently few take the chance, preferring more traditional approaches like the building of expensive mock ups; the use of labor, time and money intensive trials, and incurred costs of waste.

While all of this bodes well for an anecdotal argument supporting M&S, what's needed is a more reasoned and defensible process for determining M&S investments. While few refute the intuitive benefits of M&S, PMs quite rightly argue that any tool must be first measured against its potential benefits before it is used. Unfortunately, the question is not easily answered. It depends on a variety of factors, including the project's funding, time period to recoup the investment, and perceived benefits to developing and using M&S in the program. The crux of the problem is the dilemma of costs versus risks and the potential return. Those who develop and use M&S need a methodology to evaluate investment opportunities.

## **C. RESEARCH QUESTIONS**

### **1. Primary Research Question**

The main question of the thesis may be stated as: “Can a rigorous business analysis be applied to the utilization of M&S as applied to developmental testing?”

### **2. Secondary Research Questions**

The underlying questions that support this overarching question are:

- What are the background, history, policy and guidance related to using M&S in the DoD acquisition process?
- What are the detailed steps to developing an M&S business case analysis?
- How must this business case be tailored for application to developmental testing and what are the results when applied to available cases?
- What conclusions and recommendations may be drawn from the preceding information that might be applied to M&S efforts in support of developmental testing?

## **D. SCOPE OF THE THESIS**

The main thrust of the study will be to fully develop a business case analysis process for assessing the benefit of using M&S in the developmental testing community. Additionally, the thesis will explore, evaluate, and/or develop methodologies to assess the economic benefit of using M&S to enable performance of developmental testing and determine under what conditions M&S can be cost effective. Based on analysis, it will be determined if cost benefit is an effective measure or whether other extrinsic factors determine the worth of using M&S in performing developmental testing.

## **E. METHODOLOGY**

The main thrust of the research methodology shall be to apply the developed rigorous business case to several developmental testing/M&S efforts. This research will be performed through analyzing data from studies performed about previous VPG efforts. This business case will be developed and refined through application to a system that was



tested using live testing techniques and the application of VPG M&S techniques. The motivation to take this approach is to show how the business case can be applied prior to program initiation to ensure that the economic benefit of the use of M&S in a particular situation can be assessed accurately. Usually M&S are applied where possible and then its worth is determined after completion. This technique suggests that a rigorous business case has not been applied in the past. Once the analyses have been performed, then the live testing cases will be compared to determine the economic benefit of using M&S. This methodology is intended to provide credibility to the business case for using M&S in performing developmental testing.

#### **F. ORGANIZATION**

This thesis will be organized in the following manner:

- Introduction
- M&S History, Policy and Guidance
- Development of the Business Case Framework
  - STEP 1. Establish a Baseline
  - STEP 2. Establish a Vision and Direction
  - STEP 3. Quantify the Costs and benefits of Alternative/Capabilities
  - STEP 4. Evaluate Alternatives
  - STEP 5. Conduct Sensitivity Analysis
  - STEP 6. Develop a Migration Strategy
  - STEP 7. Monitor the process and Continue Feedback
- Applying the Business Case Framework to Developmental Testing
- Conclusions and Recommendations

#### **G. BENEFITS OF THE STUDY**

This thesis is timely in the sense that the DoD has created an initiative over the last five years to use SBA and M&S techniques throughout the acquisition process. The limitation of the SBA effort is that there is no clear direction or guidance for implementation of its techniques in a cost-effective manner. However, the acquisition

community has been constantly required to prove the benefits and more specifically, the cost benefits derived from the use of SBA. The thesis sponsor, US Army Developmental Test Command, will benefit from the methodology developed herein to better predict, assess, and account for the benefits associated with using M&S in their testing processes. Additionally, the Business Case Framework will provide a technique that will better allow documentation of M&S decisions that can withstand inquiries. This thesis will bring critical insights into the process necessary to determine the benefits that may be derived from using M&S in the testing process. This effort will add to the body of knowledge for the application of M&S in the acquisition community.

## **II. HISTORY OF M&S INCLUDING POLICY AND GUIDANCE**

### **A. MODELS AND SIMULATIONS**

Since the beginning of time, models have been used to represent abstract and physical phenomenon. So one should not be surprised that one of the most powerful tools being used by the defense acquisition community to include test and evaluation is modeling and simulation. Acquisition professionals are finding new, unique and challenging applications of models run over time creating a simulation of a system, subsystem, or the environment that the system is immersed in. It is indeed possible to create a synthetic environment where systems, both real and virtual, can be tested to determine the system's proper performance for its intended mission.

The word model brings to mind several mental images. Some remember the plastic pieces of an airplane, car or ship; all connected in an orderly fashion to be pulled apart, assembled, trimmed and sometimes painted. Others may remember watching an old war movie where the maneuver plans were drawn in the dirt or scale mockups used for mission rehearsals. A model is defined as a physical, mathematical or otherwise logical representation of a system, entity, phenomenon or process. A simulation can have two definitions: a method for implementing a model over time; and a technique for testing, analyzing, or training in which real-world systems are used, or where real-world and conceptual systems are reproduced by a model.

The Army has used explicit representation of combat systems, combat and other processes for a number of years. Long before the advent of computers, the Army relied

heavily upon information derived from the conduct of simulations. History contains examples of planning and rehearsing missions using sand tables, and developing force structure and tactics using substitutes for weapons and weapon systems during the Louisiana Maneuvers of 1940. The sophistication of tools used to model and simulate combat systems and combat processes evolved over the years. Many major field and command post exercises were conducted using probability tables and the rolling of die to simulate the occurrence of events. Rapid advances in computer technology sped the evolution of M&S into the synthetic environment.

During the evolution from predominantly physical representations, the Army's use of M&S continued to support a variety of applications for five major purposes: education, training, and military operations; analysis; research and development; test and evaluation; and production and logistics.

Since World War II, technology has advanced at an ever-increasing rate. This explosion of technology is moving faster than the acquisition community can acquire products. With technology we can accomplish what was once considered impossible. With the utilization of microprocessors, many new spin-off technologies are enabling new designs everywhere. Virtual reality with an interactive, computer-generated or synthetic environment is significantly changing our lives; entertainment, work, learning, travel and communications are all incorporating virtual reality. Today, information is being moved instead of people.

## **B. M&S HISTORY, POLICY AND GUIDANCE**

The following will give a brief history of modeling and simulation and the policy and guidance that direct its use in the acquisition environment. Table 1 in Appendix A

contains a detailed chronological history of M&S and the contributing world technology events that influenced its development and application.

Until as recently as the mid-1980s, the Army's development and use of M&S were accomplished on an as-needed and as-afforded basis. In the late 1980s, the advent of distributed simulation technology, led by the Advanced Research Projects Agency (ARPA) introduced the Army to Simulation Network (SIMNET). The SIMNET, coupled with a downward trend in defense budgets led the Army to seek M&S application simultaneously addressing more than one of the purposes mentioned previously. In distributed simulation technology, the Army recognized the potential for linking M&S of various types, fidelities, and resolutions, and of establishing these linkages from geographically separated sites both in the Continental United States and overseas. In addition, the Army was assigned the role of executive agent for DoD in developing the technology and infrastructure to support military applications of Distributed Interactive Simulation (DIS).

The Army introduced management of its models and simulations in the early 1980s with Training and Doctrine Command (TRADOC) Regulation 5-4. Today, the Army executes management of its M&S through the Army Modeling and Simulation Office (AMSO) with policy prescribed in Army Regulation AR 5-11. Army M&S used in the T&E process receives its vision through the Developmental Test Command's Virtual Proving Ground Master Plan.

In June 1991, the Deputy Secretary of Defense approved a plan to strengthen the use of modeling and simulation (M&S). He also designated the Under Secretary of Defense for Acquisition and Technology (USD(A&T)), as responsible for strengthening

the use of M&S in joint education and training, research and development, test and evaluation and operation and cost analysis. In June 1992, the Institute for Defense Analyses (IDA) published a report titled "A Review of Study Panel Recommendation for Defense Modeling and Simulation." IDA reviewed 179 recommendations made by 25 separate study panels, over a 16-year period, concerning defense M&S. The Defense Modeling and Simulation Office (DMSO), using this document as a conceptual foundation, reviewed and classified the recommendations and set off to plan for and implement those that provided for new and extended applications for M&S. The DMSO especially focused on systems acquisition and test and evaluation. The initiative instituted by the Deputy Secretary of Defense is now referred to as the Defense Modeling and Simulation Initiative.

Some key conclusions drawn from the IDA study were: 1) Specific areas, such as the architectural issues of interoperability and specification of standards, and the life-cycle support of defense models and simulations, deserve more attention and support; 2) There are many areas to which defense M&S either should be applied anew or extended, especially those associated with systems acquisition; 3) There are substantial needs and opportunities for improving management and coordination of defense M&S activities. Particularly of interest to this work is the fact that there is a lack of life-cycle support and methodologies to determine the life-cycle costs of defense models and simulations.

Then, in June 1993, Dr. Anita Jones, the Director Defense Research and Engineering, established the Acquisition Task Force on Modeling and Simulation (ATFMS) to recommend actions which would lead to the more effective and integrated use of modeling and simulation throughout the acquisition process. The final report of

the ATFMS, dated June 1994, concludes that 1) the effective, integrated use of M&S in the acquisition process is being impeded by the lack of an overall M&S architecture; 2) the lack of this M&S architecture has led to not getting the most out of the investment that is being made in M&S for acquisition; 3) clearly designated leadership and an appropriate coordinating mechanism are required to stimulate progress in the creative application of M&S to the acquisition process; 4) additional education and training on the capabilities and limitations of M&S are required for all participants in the acquisition process; and 5) it is time to apply advanced M&S and related tools to enhance real acquisition programs. (Parker, 1994) The recommendation of the ATFMS to develop an overall M&S architecture spurred the initiation of the development of the High Level Architecture (HLA) within the DoD.

Beginning in 1994, the Army implemented a policy that requires all Army acquisition strategies for ACAT I and II programs, subsequently expanded to Advanced Technology Demonstrations (ATD), to include a Simulation Support Plan (SSP). In this plan, the PM must lay out the functional requirements for M&S to support engineering and combat developments, test and evaluation, training, and military exercises to support the program. The PM must also develop an M&S acquisition strategy identifying resources required bringing the M&S to fruition.

Through the Army M&S Management process M&S standards categories have been developed to enable the use of M&S throughout the three Army M&S domains; Training, Exercises and Military Operations (TEMO), Advanced Concepts and Requirements (ACR), and Research, Development and Acquisition (RD&A). M&S that are developed at scientific and engineering levels are included in the RD&A domain.

Developmental Test and Evaluation using M&S falls within the RD&A domain. According to AR 5-11, Management of Army Models and Simulations, M&S developed for use in Test and Evaluation will be managed over their life cycles in accordance with the responsibilities defined in AR 70-1 and AR 73-1. (AR 5-11, 1997) Within the Army Standards Categories, there is a category called Cost Representation. This category includes the data, tools, algorithms and techniques necessary for accurately costing and consistently portraying all aspects of activities portrayed in models and simulations. The Cost Representation standards category currently lists two requirements: develop methods to cost all elements portrayed in M&S and standardize techniques for comparing costs of alternatives. To date however, this standards category group has not published anything to address their two listed categories. This group should be followed for future cost representation information. This group is lead by the Director of the United States Audit Agency (USAA) Cost and Economic Analysis Center, Ruth Johnson.

On Sep 10, 1996, Paul Kaminski signed out the DoD High Level Architecture (HLA) for Simulations Policy which designates the HLA as the standard technical architecture for all DoD simulations. (Kaminski, 1996) The HLA has been designated as the standard technical architecture for all DoD simulations. This mandate for HLA compliance supersedes all previous requirements for DoD simulations to comply with other simulation standards such as DIS or Aggregate-Level Simulation Protocol. All Army simulations will meet DoD standards. HLA establishes a common high-level simulation architecture to facilitate the interoperability of all types of simulations among themselves and with Command, Control, Communications and Intelligence systems. The HLA will also facilitate the reuse of M&S as the Army moves into an era of federations



of simulations producing synthetic battle environments across all domains and inclusion of M&S into all major acquisition programs.

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### **III. DEVELOPMENT OF THE BUSINESS CASE FRAMEWORK**

#### **A. RESULTS OF SURVEYS**

A survey conducted in 1999 by an ICAF team indicated that PMs are investing in M&S to support program development; however, “most of the investment decisions were based on intuition or need-based factors. Most decisions were made without detailed quantitative analysis (Brown et al., 2000)”. For the most part, PMs accepted modest investment in M&S because they believed that such investments would benefit the program. Most of these efforts, however commendable, usually lacked the use of a methodical cost/benefit analysis. “The lack of a structured business case analysis made it difficult, if not impossible, for PMs to articulate or substantiate their investment strategy” (Brown et al., 2000). In some cases PMs developed and explored M&S capabilities without even knowing what benefits might be achieved. Often the PM is willing to take a risk in using M&S in the development of his program with the hopes that a marginal yet unquantified benefit will be realized. The PMs in the ICAF study were “embracing new technology; however, without a sound business case approach, they could not really assess if the investment would realize considerable benefits or generate prohibitive costs” (Brown et al., 2000). Most PMs justified their M&S investment based on one or more of the following: reducing design cycle time; augmenting or replacing physical tests; helping resolve limitations of funds, assets or schedules; or providing insight into issues that were impossible or impracticable to examine in other ways. (Brown et al., 2000)

Much of the feedback from the ICAF study reflected that PMs had tried to examine and measure the costs and benefits of using M&S but without the aid of any

business case analysis format. Of the few reported to have used a disciplined approach, approaches and results varied among PMs surveyed. This use of inconsistent applications or approaches leads to mixed results that cannot be readily compared or evaluated. ‘The majority of respondents suggested the question of using M&S was not one of “Should I” but rather, “How can I?” This demonstrates general acceptance that M&S is required in an efficiently managed program, but it suggests the question, “At what cost?”’ (Brown et al., 2000) In the cases where the cost investment is prohibitively expensive or the long-term benefits are marginal, the decision-maker should select from alternatives, be it “foregoing M&S, partnership with other PMs to share costs, or leveraging the investment of others. This is an important decision, given the DoD’s current fiscal climate.” (Brown et al., 2000)

PMs want “confirmation that investment in M&S will yield direct savings within their budgets.” (Brown et al., 2000) Considering that much of the benefit of M&S investment is intangible, traditional cost benefit measurement approaches may not provide an accurate assessment. In this situation, PMs may dismiss using M&S tools if the estimated ROI is not significant for their immediate project needs. However, since some projects are relatively short-lived, the longer-term residual benefits may very well be missed due to short sightedness on the part of PMs. While traditionally the benefits of M&S tend to be discussed in terms of ROI, several alternatives for business case analysis can just as effectively justify M&S investments. “The challenge is to define an appropriate strategy and priorities to address the business value proposition.” (Brown et al., 2000)

A disciplined business case approach and methodology has many benefits. “It can help bring the aggregate benefits into focus and strengthen the argument for M&S investment.” (Brown et al., 2000) A business case analysis provides a convenient mechanism for project management to explore investment possibilities and assess the potential risks. It can be an easy-to-follow, logical thread that lays the groundwork for current and future programs to attain useful information, metrics and measures. “This approach forces a timeline, captures benefits and enables authorities to decide if the return is worth the investment in simulation technologies.” (Brown et al., 2000)

## **B. MAKING THE BUSINESS CASE**

The business case entails addressing seven basic areas in the prescribed order.

- Establish a Baseline
- Establish a Vision and Direction
- Quantify the Costs and Benefits of Alternative/Capabilities
- Evaluate Alternatives
- Conduct Sensitivity Analysis
- Develop a Migration Strategy
- Monitor the Process and Continue Feedback

(Brown et al., 2000)

Corporate America is taking a methodical approach to investment decisions regarding everything to include M&S. Although these methodological approaches are “primarily profit driven, they share common maxims of production, such as cost reduction, efficiency and cost avoidance, to that of DoD.” (Brown et al., 2000) Essentially, a business case will assist the decision-maker in evaluating which of a number of logical alternatives will best meet the objective.

## **1. Step 1. Establishing a Baseline**

The first step in this decision-making process is to establish an accurate baseline. The key in determining the success or failure of a project, program or function is establishing its current state before any changes are considered or implemented. "The baseline provides a benchmark from which decisions will be weighed and assessed." (Brown et al., 2000) Performance measures, regardless of type, must have a baseline measurement to show the changes/improvements a project undergoes as it achieves its goal. Establishing a baseline measure is essential in establishing the validity of a performance measure. A baseline measure is usually the first measure taken of a system or project. Subsequent measurement may be defined as the new baseline if substantial changes to the system make the earlier baseline obsolete or reduce the effectiveness of the particular performance measure. "The baseline should include a clear enunciation of assumptions and constraints." (Brown et al., 2000)

Assumptions are explicit statements describing the present and future environment. They reduce complex situations into manageable proportions. These assumptions normally provide some indication of the estimated future workload, the useful life of the investment or system, and the period of time over which alternatives will be compared. Assumptions should also discuss sunk costs and realized benefits, but are not included as part of the baseline. Constraints are those factors that limit alternatives. Normally they are expressed in terms of time, finances, institutional or regulatory statutes or directives and physical plant/assets.

The baseline must identify the high value portions of a program in order to evaluate the appropriateness of various alternatives. In other words, the decision-maker

must look at the areas of the program which will take the largest portion of program time in which to invest M&S resources to achieve a time benefit. Additionally, the decision-maker could also address which areas of the program are most costly and then appropriately apply M&S resources to potentially achieve a cost savings/benefit. Following an informed examination of the program being analyzed, the PM would be better able to allocate M&S spending where it would offer the greatest potential savings or benefits. The baseline must determine these high value areas for an effective business case analysis to be performed. These program specifics form the drivers to the program, which in turn drive the investment process. (Brown et al., 2000)

## **2. Step 2. Establishing Vision and Direction**

The decision-maker “must look to the future, then bridge the gap between present knowledge and that required to make future products a reality.” (Brown et al., 2000) The acquisition decision-maker or PM must establish the program's vision for using M&S. As the PM is developing his plan for use of M&S in support of his acquisition program, he should keep focused to ensure success. The PM should use the list of probing questions contained in the SBA “Cheat Sheet” which is provided in Appendix B. A performance plan needs to be established for the program that should contain performance goals and measures. Performance goals should be expressed in an objective, quantifiable, and measurable form. Performance measures should be established that are indicators for measuring or assessing the relevant service levels, outcomes or outputs and comparing actual program results with the established performance goals.

The performance plan for the program must identify the performance goals and measures that are based on the goals and objectives of the agency's strategic plan.

Performance goals that are representative of milestones in the achieving the long-term objectives contained in the organizational strategic plan should be included in the performance plan. The performance plan should establish the performance measures or indicators to be pursued in measuring or assessing the relevant service levels, outcomes or outputs and comparing actual program results with the established performance goals. Additionally, the performance plan will describe the operational processes, skills and technology, and the human, capital, information, or other resources required to meet the performance goals. The performance plan will provide a basis for comparing actual program results with the established performance goals; and describe the means to be pursued to verify and validate the measured values.

For some programs, there may be a gap between the capabilities provided by existing resources, including M&S resources and program goals/objectives as stated in program performance plans. Some performance gaps may be resolved by reengineering processes with or without the use of M&S. If reengineering of a process is needed it should be done prior to determining what M&S investments are needed to support the redesigned process.

A functional requirement analysis should be performed to determine the requirements that the M&S investment must meet to fill the performance gap. The analysis should identify: the performance criteria, goal, or ultimate output, a definition of the common uses of the M&S investment, a ranking of the requirements in order of importance, and a decomposition of functional requirements into self-contained features (GSA, 1998). To allow flexibility in evaluating various solutions, functional requirements should not be described in equipment and software terms, but in terms of:



business outcome, mission, purpose, capability, organizational program components involved, schedule and cost objectives, and operating constraints. The minimum information that should be identified by an analysis of functional requirements for an M&S system includes: system functional description, inputs/outputs, processes, data characteristics, performance criteria (accuracy, validation, timing, flexibility), interfaces, failure contingencies and security specifications.

Wherever possible, requirements for M&S systems should be stated using an open system architecture. The open system architecture should encompass the following characteristics: user applications not tied to a single hardware or system software manufacturer, new functionality added from different contracts without significant effort, other systems tied into or interfaced with the system without significant effort, and the system fits the organizational M&S architecture plan. Other agencies that may have acquired systems to accomplish similar goals should be identified and management should look for cross-agency, other M&S domain solutions or Government wide economies to avoid duplication of effort.

As with other developing technologies, "the vision should consider how M&S tools can improve program costs, scheduling and performance, and whether scientific knowledge exists to support such M&S investment." (Brown et al., 2000) The vision should drive or focus what the M&S tools should be trying to solve, not the other way around. The vision statement clearly identifies what M&S capabilities are to be achieved, without dictating how they will be accomplished.

During this program vision/direction planning effort, determining the functional requirements, feasibility, alternative, cost, and benefits must be accomplished as

efficiently as possible. An Integrated Product Team (IPT) should be formed to help ensure the program's success throughout its life cycle. The IPT will assist the program manager in completing and documenting the analyses needed for each project life cycle phase. The IPT for projects involving procurements must include procurement specialists, financial analysts, M&S experts and weapon system experts. The IPT will help identify functional requirements that describe functional and customer needs that must be satisfied by the M&S investment. The IPT must perform market research to ascertain if the market can provide the desired models and assets necessary to meet the program requirements. This market research/analysis is designed to produce a list of alternatives, with accompanying data necessary to assess affordability, benefits and costs.

Market research is done before the development of any formal requirements documents are developed. The following information should be collected during the initial market survey: 1) Availability of commercial items or other Government assets available to meet the need, and whether they might require modification; 2) The customary practices and the associated costs for customizing/modifying items to meet the need; 3) The customary practices regarding warranties and discounts for the identified products; 4) The laws and regulations which may apply to the acquisition of identified products; and 5) The distribution and support capabilities of possible suppliers. The decision on the contract type should be taken from the results of the market research. Once the vision and direction have been set and the requirements have been drafted, the cost and benefits of each alternative discovered during the market research must be quantified.

### **3. Step 3. Quantify the Costs and Benefits of Alternatives/Capabilities**

#### ***a. Introduction***

Since alternatives are logical packages of initiatives that work well together (Kidwell, 1998), one alternative is the status quo. This alternative is often identified during the development of the baseline in Step 1. In some cases, the baseline, often a physical prototype or live test, can be more cost effective than the use of M&S depending on the configuration or technology employed. "Other alternatives should represent various combinations of M&S tools that help achieve the vision." (Brown et al., 2000)

In the conceptual stages of a project, some of the detailed information about benefits and costs associated with different alternatives may not be available. For this reason, the benefit and cost analysis information should be updated and corrected as necessary as the project planning proceeds to its later phases and more information becomes available.

In determining alternatives, the decision-maker must consider both the immediate and long-term effects of each proposal. "First, what does the program need in order to perform better? Second, what does the program need to enable its survival until the next stage?" (Brown et al., 2000) Ultimately, a program must satisfy all requirements while at the same time, it must endure and survive each step of the process without being cut. "It does no good for a program to bankrupt itself with massive unfocused M&S investment early on." (Brown et al., 2000) Each investment must produce value during a timeframe that is appropriate for the program to achieve its performance goals. In order to survive, the PM must meet his near-term milestones in order to survive; therefore, he

must create a program that can withstand the tests of time. The alternatives must also consider the technological advances in M&S tools that might occur. “A program might not be justified in spending huge sums of money on M&S technology that may be superceded and rendered obsolete in 2-5 years.” (Brown et al., 2000)

The decision-maker when performing a cost benefit analysis must identify all costs that are incident to achieving each alternative. M&S can be expensive to develop, particularly in domains where the scientific principles are not fully understood as applied to the problem. While additional research can fill the knowledge voids, the cost of this research must be factored into the analysis of alternatives. These should include the opportunity costs of assets and resources, which are the alternative value foregone when an asset is used for other purposes. (DoDI 7041.3, 1995) They also include non-recurring and recurring costs. Life cycle costs should include all costs, non-recurring and recurring that occur over the life of an alternative. (GSA, 1998)

***b. Benefit Cost Analysis (BCA) Framework***

Consistent with Office of Management and Budget (OMB) Circular A-94 guidance, a BCA should encompass and address the following elements: explicit underlying assumptions used to arrive at the estimates of future benefits and costs, evaluation of alternative means for achieving program objectives, and plans for periodic, results oriented evaluation of the actual costs, benefits, and program effectiveness attributable to the investment.

***c. BCA steps***

The BCA process encompasses the following steps: (1) Identify assumptions and constraints, (2) Identify alternatives and their schedules, costs and

benefits, (3) Evaluate alternatives, (4) Perform risk and sensitivity analysis, (5) Develop performance goals and measures for monitoring the project.

The first two steps of the BCA process apply to this step of the business case analysis. The rest of the BCA steps will be applied to the latter steps of the business case analysis.

(1) Assumptions and Constraints. Assumptions are explicit statements used to describe the present and future environment upon which the benefit/cost analysis is based. The purpose of assumptions is to reduce complex situations to problems of manageable proportions.

OMB Circular A-94 requires analyses to be explicit about underlying assumptions to arrive at estimates of future benefits and costs and include a statement of the assumptions, the rationale behind them, and a review of their strengths and weaknesses. Examples of assumptions include estimated future workload, estimated useful life of an investment or system, and the period of time over which alternatives will be compared. Constraints are factors external to the relevant environment that limits alternatives to problem resolution. They may be physical, time related, financial, or institutional/regulatory. They provide boundary limits for the alternative solutions to a particular problem.

(2) Identifying and Estimating the Benefits and Costs of Alternatives. Some examples of simulation related alternatives are: do nothing, use Commercial Off the Shelf (COTS) packages or purchase new software or equipment, modify existing hardware/software, develop new software, and purchase services.

One alternative that should always be considered is continuing the status quo. Each alternative will have its own mix of resources. Costs must be identified and itemized at a level of detail consistent with the budgeting process. Alternatives will also have different benefits realization periods and some additional or direct benefits. As the project or procurement process proceeds, the BCA and budget requests will be updated to reflect the most current information on alternatives based on the project and procurement progress.

The estimate of costs and benefits of an investment or project should show the difference that results from making the investment; specifically the change in cash flows as a result of undertaking the project. Basic questions to be asked are:

- What additional funds will be required to carry out the chosen alternative?
- What additional revenues will be created over and above any existing ones?
- What costs will be added or removed as a result of the investment?

Benefit-cost analysis for M&S investments compares the costs of the M&S investment or project (whether it be a new system, a replacement system, system enhancement, or a hardware/software purchase) to the savings derived from the expected business and operational improvements resulting from the M&S investment or project. The basic elements of cost comparison are the total M&S investment/system and business costs if the system is implemented versus the total system and business costs if the system were not implemented or if the current system is continued. The savings resulting from the system implementation are associated with tangible benefits.

Additional intangible benefits are also documented and considered in the decision to approve system development.

(3) Tangible and Intangible Benefits and Costs. Consistent with OMB Circular A-94, both tangible and intangible benefits and costs should be recognized. The relevant cost concept is broader than private-sector production and compliance costs or Government cash expenditures. Costs should reflect the opportunity costs of any resources used, measured by the return to those resources in their most productive application elsewhere. A-94 provides additional guidance on identifying and measuring benefits and costs including: incremental benefits and costs and sunk costs, transfers, indirect measures of benefits and costs, multiplier effects, treatment of inflation, discount rates, and lease purchase analysis.

After the decision has been made that it is beneficial for an agency to acquire the use of a capital asset, OMB Circular A-94 guidelines should be used to perform a Lease-Purchase analysis to determine if the agency should purchase or lease the asset. Lease-purchase analyses should compare the net discounted present value of the life cycle cost of leasing with the full costs of buying or constructing an identical asset.

(4) Identifying and Estimating Costs. When considering the costs of projects/alternatives, one must take into consideration the project's total life cycle cost, as defined in OMB Circulars A-94 and A-109 to include all acquisition costs and the cost of operations.

(5) Project Life. It is often difficult to estimate the life of a project. The accepted criterion is the continued ability to generate satisfactory cash flows

or other intangible benefits. The period of time over which the savings or benefits to be gained from a project may be expected to accrue is the economic life of a project. The economic life is generally the lesser of physical life, technological life or mission/product-market life. The mission life is that period of time over which a need for the asset or program is anticipated. The physical life is the period during which a facility or piece of equipment will be available for use. The technological life is the period of time before which improved technology would make an asset obsolete. The project life of the M&S investments sometime occur several years prior to the time the project starts providing benefits. This elapsed time period between initial funding and the commencement of the economic life is referred to as lead-time. Project life consists of the total of the lead-time and the economic life.

(6) Methods of Alternative Comparison. Economic lives and lead times can vary among alternatives. The following guidelines are recommended for determining the comparison period. If both the economic lives and lead times for all alternatives are the same, there is no problem as the comparison will be between the same project life. In the case where the same economic lives and different lead times, the first year that expenditures must be made for any one of the alternatives, should be considered the base year or first year for all the alternatives. When dealing with different economic lives, one method is to let the economic life of the dominant asset prevail with subsidiary assets replaced as necessary. Another method when dealing with different economics lives is to use the shortest economic life and impute residual value in the asset with the longer life. Because of the inherent uncertainties of making estimates in distant years, in some cases it may be necessary to set arbitrary limits on the planning horizon to be used



in the analysis. This planning horizon can be shorter than the estimated economic life of the project.

(7) Cost categories. Cost categories to consider when estimating the cost of an alternative/project include the categories following, which are not mutually exclusive.

- Research and development: These costs are often associated with the development of new simulation systems and include items such as model development or test bed costs.
- Investment: Investment costs are essentially one-time costs and include costs such as: land, new construction, rehabilitation, equipment, software purchases, system development (functional requirements, design, analysis, programming, testing, conversion), and relocation.
- One-time personnel cost (recruitment, separation, training, travel, etc.)
- Value of Existing Assets Employed: This is the value of existing assets. This value is included in the investment cost only when the existing asset is currently in use on some other project, or was intended for sale.
- Terminal/residual value: This is the expected value of buildings, equipment or other assets at the end of their economic lives and is treated as a reduction in the life cycle cost of the particular alternative for which the use of the asset is intended. Residual value is the computed value of assets at any point in time. Residual value may or may not coincide with terminal value. Terminal/residual value should be applied to existing asset replaced as well as new assets being acquired.
- Operation and Maintenance Costs: These costs occur continually over the useful life of the project. They include labor costs of operating and maintenance personnel, fuel and power costs, operating and maintenance supply costs, spare and repair parts costs, insurance costs, taxes, and a share of indirect (overhead/burden) costs. These costs can be substantial and occur over time until the structure, system or equipment is retired from service.
- Variable costs: These are a group of costs that vary in some relationship to the level of operational activity (such as direct labor, direct material)
- Fixed costs: These are a group of costs that do not vary with output.
- Total cost: This is the sum of all life cycle costs associated with the product/system.
- Unit cost: This is the total cost divided by some related base and may be expressed in terms of cost per item produced, per person, etc. Unit cost

represents an average that may change with the magnitude of the numerator, denominator, or both.

- Recurring and nonrecurring costs. Recurring costs are those costs that occur from one period to the next at specified intervals; whereas, non-recurring costs are one-time, non-repetitive costs. Life cycle costs embrace all costs, non-recurring and recurring that occur over the life of an alternative.
- Sunk Cost: These are costs that have already been incurred and cannot be recovered or altered by future action. They are irrelevant to the benefit-cost analysis because only the future consequences of investment alternatives can be affected by current decisions.

For the more avid reader, the definitions of the cost factors that apply to these cost categories can be found in Appendix C.

(8) Cost Estimating Techniques. A thoroughly reasoned benefit-cost analysis requires the collection of financial information called cost elements from budget documents along with estimates of proposed simulation investment/system costs. The selection of cost estimating techniques depends on the amount and detail of available data and the time and resources available to develop the cost. The required level of effort for the different estimating techniques ranges from extreme analytical detail to intuition. The three cost estimating techniques are the bottom-up method, parametric analysis method and the analogy method.

The industrial engineering/bottom-up method consolidates estimates from several separate work segments into a total project estimate. It involves segmenting the total product into single parts for which detailed estimates can be established. Where detailed data exists, the industrial engineering approach can result in extremely detailed and complete estimates.

The parametric cost estimating or parametric analysis method focuses on what the project is supposed to accomplish or yield compared to similar

projects. The yield or benefits form the basis or parameters for the cost estimates. Once these benefits and their measures are established, relationships between the parameters and their costs are developed, mainly from historical data. This method is used when data is inadequate for employing the industrial engineering approach. It is also a preferred method for deriving cost estimates at the earliest stages of development.

The analogy method uses judgment, specifically analogies, which are direct comparisons with similar, historical systems or products. This method requires expertise and intuitive reasoning. When little historical data is available and neither the industrial engineering nor parametric methods can be used, the analogy method is used but it is seldom the most accurate.

In developing cost data for a life cycle cost analysis, one should initially investigate possible data sources to determine what is available for direct application to analysis objectives. If the required data are not available, the use of parametric, cost estimating techniques may be appropriate. Existing data banks, initial system planning data, supplier documentation, reliability and maintainability predictions, test data should all be investigated as potential data sources.

(9) Identifying and estimating benefits. All benefits resulting from each alternative should be identified. Both quantifiable and non-quantifiable benefits should be identified and described. Determining benefits is the most difficult part of the benefit/cost analysis because it is often difficult to identify all benefits and accurately quantify and monetize them. OMB Circular A-94 suggests the principle of willingness-to-pay to obtain a given benefit and that market prices are a good place to

start. To the extent possible, benefits should be expressed in quantifiable terms and clearly linked to the program goals and needs identified in previous planning stages.

Most benefits will be in terms of improvements in effectiveness, efficiency, or customer satisfaction. Example areas of benefits include: operating efficiency, reliability/maintainability, accuracy manageability, availability service life, quality ecology, economy morale, safety security, and regulatory compliance. Examples of types of quantifiable and monetizable benefits are: reduced resource requirements (such as support services, supplies, personnel, training, lease, rental, maintenance, computers), improved data entry (resulting in reduced staff time, lowered error rates), improved operational effectiveness (resulting in reduced error rates, improved timeliness, increased productivity, better quality products), cost avoidance (by eliminating future staff growth, minimizing penalties for delays, elimination additional equipment requirements).

***d. Benefit-Cost Analysis Framework.***

The decision to undertake a simulation investment or project is based on the assumption that the business improvements resulting from the system exceed the costs of modifying business operations and maintaining the current simulation or system (if it exists). Benefit-cost analysis makes explicit the assumed business rationale that justifies investments in simulation versus live systems. Benefit-cost analysis has four major elements: total business and system costs with the simulation investment/new system, total business costs without the simulation investment/new system, tangible benefits, and intangible benefits.

The determination of costs and tangible benefits is based upon five basic cost elements:

- Business costs with the simulation investment new system--The total costs to carry out the business functions and processes to be automated by the simulation investment/system.
- Business costs without the simulation investment/new system--The total costs that would be incurred to continue the business functions and processes with the current level of automation (which may be no automation).
- Nonrecurring costs of the new system--One time expenditures that will be incurred in the design, development or acquisition, and implementation of the new system. These expenses will not be incurred after a system is operational.
- Recurring costs of the simulation investment/new system--Ongoing expenses that will continue throughout the investment's/system's life cycle. Most of these costs will be incurred during the operational phase of the system.
- Costs to continue the current system (if there is one) --The expenditures that would be made if the organization continued to operate the existing system (these may include recurring and non-recurring costs).

Business costs are presented as a total budget projection for the business operations affected by the proposed simulation investment/system. Analysis of business costs should consider the same factors that are applied in developing multi-year budget projections. The estimates for the benefit-cost analysis should be comparable to those produced in other budget exercises.

Costs of a simulation investment/system are the costs required to design, acquire, develop, implement, and operate the simulation investment/system. These are the costs related to the simulation/system itself and not the business functions supported by the simulation/system. Costs include both business and system costs with and without the simulation investment/system. This cost comparison quantifies the financial impacts of a "go" or "no go" decision.

The cost of operating the business without the simulation/system highlights the investment managers would be forced to make in maintaining current business practices and system operations. The cost of operating the business with the new or enhanced system highlights the tangible bottom line payoff of the proposed system. Total costs with the simulation investment or new information system will, in most cases, be more than continuing current operations. Savings can accrue in the business operations that exceed the additional costs associated with design, development, acquisition, and maintenance of the simulation investment/information system itself over a projected life cycle.

Tangible benefits can be measured as specific cost savings to the organization. Tangible benefits are the cost savings resulting from changes in business and system operations. Each item in the cost analysis that has a projected saving must be associated with an operational change that will produce the reduction in projected expenditures. For example, the cost of continuing operations without the simulation investment/new system may include the hiring of additional technical staff to continue to manually process projected increases in workload. If the proposed simulation investment/system were implemented, technology would replace these manual processes and no additional personnel would be hired.

Intangible benefits are difficult to measure in financial terms. Despite their lack of financial rationale, they may be sufficient to justify the system independent of cost. In the Federal environment, compliance with legal and regulatory requirements is an intangible benefit that can, on its own, justify the investment in information and simulation systems. Other examples of intangible benefits are improved customer

satisfaction, faster service, and increased employee job satisfaction. Intangible benefits must be supported by a clear link to specific outcomes of system implementation.

(1) Benefit-Cost Model Components. This section presents a discussion of the information collection requirements for the proposed benefit-cost model. It is organized around identifying fully allocated current simulation/system costs and proposed project expenses. Growth values such as present value calculations, cost of money and interest expense are factored into this model. The model is expressed as simply as possible and is consistent with Federal guidelines governing benefit-cost analysis.

Information collection is intended to reflect a mixture of cost projections and assumptions that system owners have gained through operating experience. Information concerning new proposed systems should be organized and recorded on the project worksheet (Figure 1. Benefit-Cost Calculations). Backup documentation to this cost worksheet should be explained in a narrative form sufficient to clarify assumptions about the numbers. Complete information describing the current systems should also be provided along with any foreseen benefits from continuing current operations.

CALCULATION	FORMULA				RESULT
Business Savings	Business Costs Without the New M&S System	- Business Costs With The New M&S System	= Business Savings	x Present Value Factor	= (a) Present Value of Business Savings
Net System Costs	Recurring Non-Recurring Costs of New M&S System	+ Costs of Continuing Old System	= Net System Costs	x Present Value Factor	= (b) Present Value of Net System Costs
Benefits	Present Value of Business Savings (a)	- Present Value of Net M&S System Costs (b)			= (c) Net Present Value of Benefits
Benefit-Cost Ratio	Present Value of Benefits (c)	- Present Value of Net System Costs (b)			= Present Value Benefit-Cost Ratio

Figure 1. Benefit-Cost Calculations. (GSA, 2000)

The model is designed to allow comparison of costs with and without the simulation investment/new system: non-recurring costs, recurring costs, residual values and benefits over an estimated systems life. Each benefit-cost worksheet should be carefully analyzed to ensure completeness in capturing fully allocated cost projections.

The cost worksheet should be completed for the full life cycle of the proposed simulation project/system. The life cycle includes design, acquisition, development, implementation, maintenance, and disposal. Supporting documentation should identify the expected time period for each life cycle stage of the system. A six year system life cycle is assumed in this methodology. Six years reflects the impact of rapidly changing simulation technology on the useful life of systems. Some simulation/systems may have a longer or shorter life cycle. In these instances the benefit-



cost analysis should include the rationale for the life cycle. The methodology and supporting worksheets can be adjusted to fit the projected system life cycle.

(2) Business Operation Costs. This category of cost elements identifies the total costs to carry out the business functions first with the current level of automation and then when they are automated by the simulation investment/new system. The costs need to be calculated both with and without the proposed new simulation system. Business operations are the activities and resources used to conduct the functions to be supported by the proposed simulation system. Business operation costs are defined by the following cost factors: personnel salaries and fringe benefit, supplies/equipment, facility space occupancy, utilities, maintenance, travel, training, incidentals, interagency, and other identified costs.

(3) Nonrecurring Costs of the Simulation Investment/New System. This category of cost elements identifies the one-time expenditures that are incurred in the design, acquisition, development, and implementation of the new simulation system. Nonrecurring costs of the new system are defined by the following cost factors: conversion costs, replacement or upgrade systems, hardware, software, communications, contracting, travel, training, studies, parallel operations, incidental expenses, residual value, and other identified costs.

(4) Recurring Costs of the Simulation Investment/System. This category of cost elements identifies the ongoing expenses that are incurred to maintain and operate the simulation/system after implementation is completed. Costs should be projected for the entire useful life of the system: parallel operations, hardware lease or rental, software lease or rental, communications, other equipment, facility space

occupancy, utilities, maintenance supplies, personnel salaries and fringe benefits, security, travel, training, system testing and back-up, incidentals, interagency, and other identified costs.

(5) Costs of Continuing the Existing Simulation System. This category of cost elements identifies the simulation system costs that would be incurred if the existing level of automation or simulation were continued instead of developing the new system. The costs of continuing the old simulation/system are defined by the following cost factors: hardware lease or rental, software lease or rental, communications, other equipment, facility space occupancy, utilities, maintenance, supplies, personnel salaries and fringe benefits, security, travel, training, system testing and back-up, incidentals, interagency, and other identified costs.

(6) Calculated Values. In order to compare costs and benefits at a point in time, present value tables are used in the model. OMB Circular A-94 defines the standard criterion for deciding whether a Government program can be justified on economic principles as the net present value of benefits. Net present value is the projected savings resulting from the program reduced by the net investment required developing and implementing the program. Using the costs of business operations and systems described above, five basic calculations are made to assess the benefits that will result from the new system. These calculations are described below and in Figure 1.

Business Savings. Business savings is the difference between the cost of business operations without the simulation investment/new system and the cost of business operations with the new system. The result of this calculation is the business savings of the new system.

Net System Costs. Net system costs is the difference between the cost to continue to operate the old simulation/system (if there is some existing simulation/system) and the cost to design, acquire, develop, implement and maintain the simulation investment/new system. Net simulation/system costs are the additional investment that the organization will make in the simulation investment/new system or, if the simulation investment/new system is less costly, the system-related savings that will result from the new system.

Present Value Factor. Cost information is adjusted in the model using tables to multiply costs and benefits by discount factors consistent with OMB Circular A-94 guidance to determine the present value based on the year of occurrence. Note: OMB Circular A-94 is updated periodically. Those conducting a BCA should ensure that they are using the proper discount rates, consistent with the latest version of OMB Circular A-94, by checking the Internet at <http://www.whitehouse.gov/WH/EOP/OMB/html/circulars/>.

Net Present Value (Of Benefits). Net Present Value is the business savings increased or decreased by the net simulation/system costs. If the new system reduces system costs, tangible benefits will be higher than business savings. If the new system represents increased costs, tangible benefits will be less than the business savings of the new system.

Benefit-Cost Ratio. The Benefit-Cost Ratio is the value of the tangible benefits compared to the net simulation/system costs. Benefits will generally exceed costs and this ratio will almost always be greater than 1. If a system has a benefit-cost ratio less than 1, it must be entirely justified by its intangible benefits.

(7) Benefits. New simulation systems provide opportunities for a broad range of improvements to technical business operations. Not all benefits of automation will result in a tangible benefit that reduces costs. Intangible benefits can be an important factor in deciding to proceed with the development of a simulation system. Intangible benefits should be documented as part of the benefit-cost analysis and included in the narrative that describes the proposed system. Intangible benefits should be considered with the benefit-cost ratio for determining the rationale for continuing with the proposed system. In identifying tangible and intangible benefits of the new system, the following should be considered:

Reliability Improvements. The benefit gained in the reduced risk of system malfunction or failure, and reduced downtime for manual operations versus a comparison system, for performing the same or equivalent tasks.

Accuracy Improvements. The benefit gained in process simplification and streamlining. Ease of data input and accuracy rates that reduce overall errors are reported here.

Labor Productivity Improvements. The benefit gained in performing the same functions and tasks for fewer hours of personnel time. These improvements may allow staff to work on other activities, but do not result in an actual reduction in personnel.

Grade of Service Productivity Improvements. The benefit gained in performing a service more efficiently or effectively to the direct benefit of the warfighter or taxpayers.

Compliance With Legal And Regulatory Requirements. The benefit gained by meeting procedural or performance guidelines specified in laws and regulations. Physical environmental limitations can often be overcome by stimulating the live system with a simulated environment created with a model.

Customer Satisfaction. The benefit can be in terms of a reduction in time spent analyzing data and an ability to answer questions with more accuracy in a timelier manner.

*e. Quantify the Cost and Benefits of Alternatives/Capabilities Reprise*

Identifying alternatives can be the most difficult portion of the process. Benefits must be viewed primarily in terms of measurable value. Expected benefits should flow from the clear operating vision developed in Step 2 of the business case. Enigmatically, there are both quantifiable and non-quantifiable benefits. The former usually have some tangible or readily identified returns; the latter have less so. Additionally, there may be benefits that have no intrinsic value to one program but provide value to others which are called external benefits.

(1) Quantifiable Benefits. These include cost savings, time improvement, acceleration of deliverables, quality enhancement and, in most cases, cost avoidance that is directly related to the program. The alternatives must also consider existing systems and programs. If improvements are to be measured from an “as-is baseline” – then it is not advisable to start from ground zero. It may be possible to look at related M&S domain initiatives in other programs, assess their applicability, and leverage them for success. The cost associated with using these existing alternatives should be less, given that a majority of the investment would be a sunk cost borne by the

previous developers. Similarly, it is also advisable to consider partnering with another program and thereby sharing costs. This option is a possible alternative to reducing the up-front investment required for a new development effort. One should ensure that they have examined all potential benefits by using published references and experts in the field of cost analysis.

(2) Non-Quantifiable Benefits. Traditionally, the issues of risk reduction, organizational efficiency, technology transference, product safety, and environmental impact reductions have been considered as non-measurable and therefore non-quantifiable. However, these are important issues, and one must consider them in their analysis. To illustrate this point, technology transference will be addressed.

M&S technology transference can significantly influence costs, but in today's DoD environment it has yet to receive adequate attention. Given the shrinking public purse and the demand for greater accountability and responsibility for the dispersal of funds, all must show due diligence in their public spending. They must consider the residual benefits of technology transference.

Some M&S investment might be of use to other projects and Program Managers. For example, the Grizzly PM invested heavily in chassis M&S to support short-term design and performance analysis. This M&S investment resulted in \$21 million worth of quantifiable benefits to the Grizzly program. The Grizzly PM funded the M&S effort through internal reallocation of funds. The PM's supervisor, PM Combat Mobility Systems, recognized the potential for the use of these models for both other program requirements and in other programs sharing the Grizzly's chassis. He leveraged the Grizzly Program's M&S investment, securing funding to expand the applicability of the initial investment into other programs and to support other long-term Grizzly requirements. (Brown et al., 2000)

When forecasting near-term savings in design and production costs, one company in the ICAF study accrued substantial non-quantifiable benefits.

“The engineers made a substantial leap in M&S knowledge when learning how to define data needs, how to shape models, and how to refine simulation runs, to narrow the bandwidth of problem solving. The resulting expertise, data and process could be applied to future projects.” (Brown et al., 2000) Not surprisingly, the company’s models and databases are the envy of the industry based on their visionary efforts. These efforts helped the company achieve a competitive advantage that was a non-quantifiable gain.

Unfortunately, many decision-makers and PMs dismiss the concept and viability of non-quantifiable benefits. “Organizations rarely track non-quantifiable benefits or those outside the program’s realm with any real vigor. They don’t afford them reasonable weight when analyzing costs and their alternatives.” (Brown et al., 2000) Similarly, external benefits almost always exist. Usually, these benefits that are applicable to the Government and DoD at large are not acknowledged due to the not invented here mentality.

External Benefits are benefits which do not bring direct return or savings to the unique program being managed, but have applicability to other organizations. As mentioned previously, many M&S initiatives and their products can either be modified or directly transferred to other programs. Looking again to the Grizzly program, the contractor supporting the PM, United Defense Limited Partnership, developed a common product model database that benefited efforts at Aberdeen Proving Ground, The Army Warfighting Analysis and Integration Center, Waterways Experiment Station and National Training Center projects (Brown et al., 2000). This example shows that there is a residual savings or external benefits for follow-on users. PMs have identified problems with the high cost of collecting data and maintaining the databases

which can benefit other programs in the future. There is no focus in the acquisition community to address and incentivize PMs to address the external benefits of their programs. While the cost of performing this might be high, or perhaps even prohibitive to one project, it could be cost effective to several other end users. "Institutional bias forces PMs to ignore external benefits. A PM has no incentive to take on an M&S investment unless he can justify the expense from his existing program." (Brown et al., 2000) Even though, according to DODI 7041.3, societal costs and benefits outside the Federal Government are usually not included in a DoD Analysis, it is pertinent from a business perspective to consider external benefits.

Perhaps the real value of identifying quantifiable and non-quantifiable benefits is in helping others outside the program to realize potential synergies of reuse. For example, the Program Executive Officer (PEO), who is charged with oversight of this program and many other related programs, will have better visibility into requirements and the potential benefits. He can more accurately assess M&S investment in relation to a broader spectrum of programs. Operational analysis and training are just a few examples of synergies of reuse between acquisition communities where M&S products developed for testing can be transferred and used for other uses. Many of these benefits, while external to an individual PM, may be internal benefit from the PEO's perspective. The PEO must be provided with the data and information drawn from the business case analysis performed by an individual program under his purview in order to make sound management decisions. Based on the information provided in the business case analysis, the PEO can choose to redirect funding from other sources into the program, and/or direct a PM to take a course of action. This PEO action may not be



cost-effective in a micro-perspective for an individual program; but will bring an aggregate gain that far outweighs the individual investment. (Brown et al., 2000)

#### **4. Step 4. Evaluate Alternatives**

To evaluate the alternatives, the costs and benefits of each alternative must be compared and then ranked. Such comparisons must be accomplished using both quantitative and qualitative techniques and criteria. Quantitative techniques include net present value, benefit cost ratio, return on investment, payback method, internal rate of return, hurdle rate, and cost effectiveness analysis. Qualitative evaluation considerations such as relationship to business strategy, schedule risk, organizational and technical risks, social benefits, and legal and regulatory requirements may greatly alter the quantitative ranking.

The choice of appropriate tools is program and situation dependent, and can greatly influence the outcome of the analysis. These tools will aid decision-makers in accurately evaluating all alternatives such that all costs and benefits are viewed on a level playing field. In general, each feasible alternative, life-cycle costs and benefits are adjusted using discount factors to account for the time value of money. A complete analysis properly relates quantitative and qualitative factors. Given the importance of these choices, one should seek expert advice and guidance before proceeding.

One such tool is the Cost Analysis Strategy Tool (CASA). CASA is ideal for conducting life cycle cost estimates to include supportability-related trade-off analyses, sensitivity analyses and comparing different systems and alternative support structures.

The CASA model is a life cycle cost decision support tool for Program Managers responsible for materiel acquisition systems; however, it can be reasonably used for the

acquisition of models and simulations. In particular, CASA addresses the Total Ownership Cost (TOC) for the objective system including research, development, test, and evaluation; manufacturing development and production; and the entire operational life during which the system must be supported. Virtually, every cost associated with a system is covered by CASA, whether one-time, recurring, or annual.

The CASA model has extensive analytical capabilities. In addition to calculating life cycle cost estimates and identifying cost drivers, CASA also performs trade-off and sensitivity analyses. A wide range of sensitivity analyses can be conducted on the various cost parameters included within the CASA model. With this capability, the user can examine the cost impact of varying factors such as support equipment availability or the turnaround time for spare parts. The production rate and quantity buy analysis option assists users in determining the optimum quantity of times to procure. The robust CASA life cycle cost model can consider life-cycle studies for projects that last up to 50 years and accommodate customized maintenance schemes with up to 10 levels. CASA is a powerful tool for developing life cycle cost estimates and gaining a better understanding of the resultant cost figures through trade-off and sensitivity analyses. CASA 2000 is available online at <http://www.logsa.army.mil/alc/casa>. (McPherson, 2001)

*a. Quantitative and Non-Quantitative Evaluation Methods*

Simulation investment alternatives should be evaluated using multiple decision attributes that include both financial and non-financial criteria. The system or process for analyzing costs and benefits associated with and investment should include qualitative and quantitative criteria of a financial and non-financial nature.

(1) Quantitative Methods. This section addresses the quantitative methods of estimating and comparing costs and benefits of different alternatives. This section will refer often to entries developed in Figure 1. Benefit-Cost Calculations in Step 3 of the business case. Figure 1 provides a model and worksheet that can be used to perform the quantitative analysis and calculations of the benefit cost analysis. This section will provide the quantitative analysis methodologies.

(2) Net Present Value (NPV). Per OMB Circular A-94, NPV, the discounted monetized value of expected net benefits, is the standard criterion for deciding whether a Government program can be justified on economic principles. Net present value is calculated by assigning monetary values to benefits and costs, discounting future benefits and costs using an appropriate discount rate, and subtracting the sum total of discounted costs from the sum total of discounted benefits. Discount rates and the discount factors to be used are provided and defined in OMB Circular A-94.

Present value analysis is based on the principle that benefits accruing in the future are worth less than the same level of benefits that accrue now and costs that occur in the future are less burdensome than the costs that occur now. The formula for calculating NPV is:  $NPV = \text{Present Value of benefits} - \text{Present Value (PV) of costs}$ .

The present value of a benefit or cost is calculated by multiplying the amount by a discount factor. The discount factor is equal to  $1/(1+i)^n$  where  $i$  is the discount rate and  $n$  is the number of periods over which discounting takes place. If the NPV is positive, the financial return on the project is economically acceptable. This is because the cash flows generated by the investment over its economic life will: recover

the original outlay and any future outlays, earn the desired return on the outstanding balance, and provide a cushion of excess economic value. If the NPV is negative, the project is not acceptable on economic grounds.

Additional methods of evaluating costs and benefits are available to help distinguish among alternatives with similar NPVs or ones where it is difficult to estimate present value. OMB Circular A-94 recommends that when a net present value cannot be calculated, agencies provide a comprehensive enumeration of the different types of benefits and costs and/or quantify benefits and costs even though it may not be possible to monetize them.

(3) The Benefit Cost Ratio (BCR) or Profitability Ratio. The BCR measures the economic desirability of an investment by dividing the present value of its benefits (cash inflows) by the present value of the costs (outflows). The alternative with the highest BCR is the most cost effective because it returns the most benefits per dollar spent. The formula for this ratio is:  $BCR = PV(\text{benefits}) / PV(\text{costs})$ . The BCR provides a measure of the benefits obtained per dollar spent. The higher the BCR the larger the return. Whereas the NPV is an absolute measure that refers to a specific set of values, the BCR allows comparison of different projects. In selecting among alternatives the BCR shows which alternative provides the largest return relative to costs.

(4) Return on Investment (ROI). The ROI ratio is calculated by dividing the average annual operating cash inflow (benefit) by the annual net investment. All this ratio does is calculate what percentage of the investment the annual benefit cash flow is. This amount is calculated on an annual basis and the formula for this ratio may be calculated as:  $ROI = \text{Average annual operating cash inflow} / \text{Net}$

investment. This ratio is limited in its usefulness because it does not take into consideration the economic life of the project and assumes a constant annual return. The ratio also ignores the time value of money and, therefore should not be used except in relation to annual returns or when speaking in generalized or gross terms.

(5) Payback Method. This method estimates the time it takes to recover the original investment outlay. This value is calculated by dividing the net investment by the average annual operating cash inflow:  $\text{Payback (time)} = \text{Net investment} / \text{Average annual operating cash inflow}$ . This ratio gives a very rough test as to whether the investment will be recovered within its economic life span, however this ratio is limited in its use as it is insensitive to the economic life span and assumes constant annual operating cash inflows. It does not consider cash flows beyond payback and, therefore, does not measure profitability.

(6) Internal Rate of Return (IRR). The IRR method determines the discount rate that makes the net present value of a project equal to zero. When applied to both cash inflows and cash outflows over the project's economic life, it provides a zero net present value so that the present value of the inflows exactly equals the present value of the outflows.

(7) Hurdle Rate. The hurdle rate is a minimum standard for the return required of an investment. A hurdle rate may be used to help select from among alternative investments when other decision criterion is lacking. For instance, a hurdle rate equal to the cost of capital as reported by the Treasury Department may be used.

(8) Cost Effectiveness Analysis. OMB Circular A-94 states that cost-effectiveness analysis is appropriate wherever it is unnecessary or impractical to

consider the dollar value of the benefits provided by the alternatives under consideration. A program is cost effective if, on the basis of life cycle cost analysis of competing alternatives, it is determined to have the lowest costs expressed in present value terms for a given amount of benefits. Cost-effectiveness analysis is appropriate whenever: (1) each alternative has the same annual benefits expressed in monetary terms or (2) each alternative has the same annual effects, but dollar values cannot be assigned to their benefits. Cost-effectiveness analysis can also be used to compare programs with identical costs but differing benefits. In this case, the decision criterion is the discounted present value of benefits.

***b. Non-Quantitative Evaluation Considerations***

A non-quantitative evaluation approach often has to be used when there are limited measures or metrics available for a proposed simulation approach. Qualitative evaluation considerations including non-quantifiable or monetizable benefits may override quantitative criteria in the ranking or acceptance of projects. Such considerations include: relationship to business strategy, schedule risk, organizational and technical risks, social benefits, or legal/regulatory requirements. Non-quantifiable considerations for evaluating alternatives should be identified in the BCA.

(1) Identifying and Evaluating Risks. Benefit and cost estimates are typically uncertain. Having a strategy to deal with the risk that is inherent in large simulation investments/projects is critical. One of the greatest risk factors to the success of simulation projects is the amount of development that is planned. Full-scale development is where the potential is greatest for significant cost and schedule overruns and lowered performance goals. The types of risks encountered in a simulation project may include: schedule risk, risk of technical obsolescence, cost risk, technical feasibility,

dependencies between a new project and other projects or systems, and the risk of creating a monopoly for future procurements.

(2) Risk Management. Risk management is an organized method of identifying and measuring risk and developing, selecting, and managing options for handling risks. Risk management consists of four elements: risk assessment, risk analysis, risk treatment and risk management plan. Risk assessment which identifies and assesses all potential risk areas, any parts of a project where there is uncertainty regarding future events that could have detrimental effect on meeting the program goal. Risk assessment continues throughout the life of the project as previous uncertainties become known and new ones arise. Risk analysis characterizes each risk as to the likelihood of its occurrence and the severity of its impact. It results in a watch list of potential areas of risk. Risk analysis also continues throughout the life of the project. Risk treatment determination is made after risk has been assessed and analyzed. During risk treatment, a determination is made for how to deal with it. Alternatives include:

- Transfer - risk may be transferred to another program or phase of the program, another Government service or a contractor.
- Avoidance - it may be determined that the risks of any particular solution/alternative are too great and the alternative should be removed from further consideration.
- Reduction - necessary measures can be identified to minimize the likelihood of a risk occurring and/or minimize the damage of its impact on program goals should it occur.
- Assumption - a decision may be made to assume a risk if effective control can be exercised, the probability of risk is small, or the potential damage is either minimal or too great for another program or Government service to bear.
- Sharing - if a risk cannot be appropriately transferred and should not be assumed, it can be shared with another program or Government service, or a contractor.

(3) Risk Management Plan. A risk management plan should be developed that includes information on the types, probability and impact of risks pertinent to the simulation project, including the risk that the funding request will not be approved or not approved in its entirety and plans for how to treat and manage the risk, to include how to respond to lower funding. Furthermore, requiring a higher return for projects determined to be of higher risk can accommodate risk. Also, risk analysis estimates of the probability that a simulation investment will fail and the impact this would have on the business can be subtracted from the expected benefits to adjust the ROI or NPV calculations to reflect risk.

Sophisticated risk assessment methodologies, such as, probabilistic simulation can be used to estimate ranges for total annual cash flows and key variables can be identified. Probability distributions can then be assigned to the outcomes for each of the variables. Computers can be used to run multiple iterations. A contractor can perform an independent risk analysis of the selected approach or alternative and the ROI can be adjusted accordingly.

## **5. Step 5. Conduct Sensitivity Analysis**

Sensitivity analysis is an essential step in the decision process as it accounts for ever-present uncertainties and variable changes. Such analysis repeats the evaluation of alternatives performed in Step 3 but with changes to the uncertain variables and examines the effect on the final decision. The outcome of the sensitivity analysis will provide a better understanding of the robustness of the output of the business case analysis.

Sensitivity analysis is highly recommended, even if there appear to be significant differences among the alternatives, because an apparently superior solution may be very



sensitive to changes in a single variable. Sensitivity analysis is required when differences among alternatives are less obvious and may be totally driven by variability of key input factors. "The key factors to be tested may include, but are not limited to; project or program length, volume or quantity and mix of production units, requirements, configurations, assumptions, and discount rates and other economic factors." (Brown et al., 2000)

To conduct the sensitivity analysis, all parameters in the analysis are held constant except the factor being tested. The analysis is then reworked using different estimates for the factor under review. If this results in changes to the ranking of alternatives, the analysis is sensitive to that amount of change in the variable. Each parameter should be tested individually to determine its effect on the analysis.

Sensitivity refers to the relative magnitude of change in one or more elements of an economic analysis that will cause a change in the ranking of alternatives. Sensitivity analysis is used for assessing the extent to which costs and benefits are sensitive to changes in key factors. In a sensitivity analysis, if one particular factor or cost element can be varied over a wide range without affecting the ranking of alternatives, the analysis is said to be insensitive to uncertainties regarding the particular event. A sensitivity analysis can provide a range of costs and benefits that are likely to be a better guide than a single estimate.

If there is certainty and the preference ranking establishes one alternative as markedly superior to the rest, sensitivity analysis is probably unnecessary. However if there is uncertainty with at least some of the assumptions and the alternative of choice is not clearly preferable to the rest, then a sensitivity analysis may be necessary.

As part of the sensitivity analysis, major assumptions should be varied and net present value and other outcomes recomputed to determine how sensitive outcomes are to changes in the assumptions. Assumptions deserving the most attention will depend on the dominant benefit and cost elements and the areas of greatest uncertainty. For each alternative, key high risk factors should be changed to a less favorable number to test sensitivity. Key elements to evaluate include: length of project life; volume, mix, or pattern of workload; requirements; configuration; assumptions; discount rates; and cost and benefit estimates. (GSA, 2000)

## **6. Step 6. Developing a Migration Strategy**

After determining the best alternative, one must develop a sound implementation plan to migrate the chosen strategy into the program (Brown et al., 2000). Cost, schedule and performance goals must be formalized in order to manage the investment/project. The plan for migration must incorporate a systematic approach to ensure the developer implements the identified drivers and captures the expected benefits. The performance goals should stem from the needs/requirements that alternatives are fulfilling and should address the benefits they are expected to provide. Performance goals should be consistent with the organization's strategic plan goals and should be linked to or part of performance plan goals and measures. Schedule and cost goals must also be established to help ensure projects adhere to planned costs and schedules. Interim annual goals and measures must be established for multi-year projects to ensure timely detection of problems and implementation of corrective action. Implementation of the migration strategy will undoubtedly force changes to the program's plan and budget. If a new tool or process is expected to save money, then those savings should be subtracted from that part of the program budget and reassigned elsewhere as an up-front action.

## **7. Step 7. Monitoring the Process and Assessing Results through Formalized Feedback**

The final step in developing a business case will be to create metrics to assess progress towards the overall vision. These metrics should be tied to the changes made to the program's acquisition plan, to provide timely feedback on their success in meeting desired results in performance, schedule, and cost. Performance metrics should stem from the needs and requirements that alternatives are fulfilling, and should address the benefits they are expected to provide. Schedule and cost metrics must also be developed to help ensure programs adhere to planned costs and schedules (Kidwell, 1998; GSA, 1998).

Since PMs face tremendous pressure to bring a product into use, they must deliver their programs with complementary benefits first. This is their true priority, but they should also identify real or potential external benefits up the management chain to the PEO. That office can then make more informed decisions on the macro benefits. PMs should consider increasing investment earlier in the program if the business case strongly indicates downstream savings as a result. PEOs can provide the attendant oversight and direction, with a requisite re-allocation of funds when it is in the DoD's best interest to do so. (Brown et al., 2000)

Monitoring needs to be a truly integrated process, with all elements actively involved. A sharing of analysis, combined with a DoD commitment to maximize and optimize any potential benefits of M&S technology, will bring unprecedented reward in cheaper, better, stronger products and the associated prudence in managing the public resources. Conducting a Post Implementation Review that includes financial data, using

measures and metrics developed enables the monitoring; feedback and continuous improvement of the M&S product and development process.

***a. Conduct Post Implementation Review***

Once a system becomes fully operational or implemented, a Post Implementation Review (PIR) will be conducted. This review should occur about 3 to 6 months after the project has become operational. It is highly recommended that the review be conducted by a group other than the IPT that has been responsible for the development of the system. This ensures that it is conducted independently and objectively. Subsequent PIRs should be conducted on a periodic basis after the first PIR to ensure that the completed system is continuing to meet organizational and user needs.

Each PIR that is conducted has a dual focus. First, it provides an implementation assessment of the system, including an evaluation of the development process. Secondly, it indicates the extent to which the business case steps are sustaining or improving the success rate of M&S projects. The following areas should be evaluated as part of a complete PIR. Each topic should be documented with a summary of findings that support the conclusions and recommendations. Additional Documentation and Project Risk Checklists are included in Appendices D and E.

***b. Post Implementation Review Assessments***

(1) Mission. An analytical approach should be taken to determine whether the implemented system has achieved its proposed impact on the agency's business. It is important that all agency M&S investments are aligned with the organization's mission and the agency's program objectives. Additionally, M&S investments are to be analyzed and evaluated in respect to the overall benefits for DoD business practices. The PIR team is obligated to determine the status of several project

variables, including the delivery of services or products estimation of cost savings, compliance with the DoD High Level Architecture, evaluations of the information product, e.g. accuracy, timeliness, adequacy, and appropriateness of information, identification of additional maintenance and security.

(2) Systems Description. A specific description of the functions of the system should be documented. The tasks performed and the approach taken to accomplish each task and the resources used also needs to be outlined. All hardware, software, and applications software associated with the system should be documented as well. All personnel requirements and geographic locations that provide input, receive output, or assist in system processing should be identified. Finally, there should be an explanation of how the system contributes to the organization's mission.

(3) Change Control. The Change Control process and procedures for the system should be documented and evaluated for efficiency. A determination should be made of the number and severity of the changes to date and their impact on the stability of the system. An assessment should also be made describing the system's ability to respond to changing requirements.

(4) Operation. An analysis of the system operation, including hardware, system and application software should be conducted and compared against those projected. Finally, recommendations regarding system changes and redesign based on projected comparisons and operation problems.

(5) Security. A security evaluation should be conducted to verify that the appropriate security requirements are documented and enforced. If problems are identified in this area, these should be outlined and corrective actions need

to be identified. Any security or risk incidents need to be identified and analyzed for potential system weaknesses. An evaluation should be made of the cost effectiveness of system security measures and recommendations made where improvements can be made. Finally, the contingency plans need to be checked to ensure that they are current and are feasible to minimize loss from threats and equipment/software malfunctions.

(6) Outputs. The outputs of the new system, e.g. reports, data, or formats, need to be compared to those that were initially proposed. The impact of any changes on the initial design, geographic locations, or telecommunications factors should also be evaluated and documented.

(7) Documentation. Any system documentation such as User's Guides or Operations Manuals should be reviewed for completeness, accuracy, and timeliness. A list of all required documentation should be developed and kept up to date.

(8) Management. A review of the support organization structure should be examined. The organizational structure and responsibilities as implemented should be compared against those documented during the project. The system ownership and individual authorities and responsibilities should be verified and updated, as required. Any areas where there is conflicting, unidentifiable or inappropriate management or supervision should be identified and corrected. Training issues should also be examined in this area to ensure that personnel (users and support) are properly trained. (GSA, 2000)

***c. Review and Evaluate Project Information***

In addition to the items reviewed in the Post Implementation Review, the following areas need to be evaluated and assessed:

(1) Technical Capability. The technical capabilities of the project, both current and future, should be reviewed and evaluated. Factors such as the competency of the workforce to use the new system and employee satisfaction or retention, the extent to which advanced technology was used, and the methodological expertise of the development team should be considered.

(2) Measurements of Actual vs. Projected Performance. The project's actual results should be compared to planned estimates in terms of cost, schedule, performance, and mission improvement outcomes. An attempt should also be made to determine the causes of major differences between the planned and final results.

(3) Evaluation of Outstanding Issues. If the PIR reveals issues that still require attention, these issues need to be identified and documented. The issues should clearly document the estimates of cost and time, the risks for not addressing the issue, any tradeoffs or alternatives, and provide a recommendation from the PIR review team. The issues should then be sent to senior management for evaluation and a final decision on the actions to be taken.

***d. Review and Update Financial Information & Performance Measures***

Once the actual final financial and performance measurement information for the initiative has been gathered, it should be compared against the planned results. This will allow a determination to be made as to the success of the initiative and to determine the causes of any differences between planned and actual results. The following five areas should be evaluated in this process:

- Evaluation of Cost Information – compares the actual versus planned life cycle costs for the initiative.

- Evaluation of Financial Return Information – compares the actual versus planned results for financial performance measures.
- Evaluation of Non-Financial Return Information – compares the actual versus planned results for non-financial performance measures.
- Evaluation of Acquisition and Procurement Information – compares the actual versus planned results for contract and contractor information.
- Evaluation of Budget and Financing Information – compares the actual versus planned results for funding source and general budget and financing information.

The monitoring and feedback step continues throughout the development and post deployment of the system. The collection of system, process and financial information creates a M&S development and deployment which can be audited and additionally, helps the PM achieve his programmatic goals.



## **IV. APPLYING THE BUSINESS CASE FRAMEWORK TO DEVELOPMENTAL TESTING**

### **A. INTRODUCTION**

This part of the thesis will take the business case developed in the previous section for programs in general and apply it to Test and Evaluation (T&E). The remainder of the thesis will deal primarily with the discipline of Developmental Testing (DT). T&E are essential parts of the development and deployment of all Army systems. "The information generated as a result of T&E influences every action taken during the system acquisition process." (HQDA, 1997) The Developmental Test Command (DTC), a subordinate command of the Army Test and Evaluation Command (ATEC), has the roles of developmental testing and safety certification, and advises program managers as part of IPTs.

DTC has a long history of using physical simulation as part of the process to confirm a developmental weapon system's readiness and technical maturity. M&S within the T&E process is the integration of a mix of computer simulation, actual warfighting systems, and weapon system simulators, immersed in synthetic environments, distributed geographically, and connected through high-speed networks. Simulation for T&E includes Software-in-the-Loop (SWIL), Hardware-in-the-Loop (HWIL), or Human-in-the-Loop (HITL) simulations as well as synthetic environment simulations. T&E uses M&S to identify test parameters and drivers for field tests; determine high risk areas; predict test results; assist in the allocation of scarce test resources; and provide entity stimulation in support of interoperability testing. M&S provide the only route to obtain risk-reducing system-performance data in situations that

cannot be tested due to safety, cost, or other constraints. Presently, DTC is reengineering the Army's technical test capabilities through its VPG initiative. The VPG consists of a comprehensive and interrelated set of synthetic environments, stimulators, and simulation test procedures operating within a standard architecture framework. Historical data from hardware tests on DTC ranges and other real-world test sites provide ground truth data that anchor the VPG to reality.

DTC seeks a sound business methodology to provide cost avoidance and Return on Investment (ROI) data for future tests using M&S. DTC needs the data to ensure that it can recommend the right mix of live testing, which validates the M&S, and use of the VPG or virtual testing, that augments the live testing. The cost data help DTC encourage investment in its live and VPG facilities and technologies. "M&S is useful for aiding in test design and making pre-test predictions. Test results are invaluable in validating and improving models and simulations" (Coyle, O'Bryon & Hillegas, 2000). These data will be most credible to customers if developed as applications of Government approved methodologies. DTC therefore seeks to ensure that its VPG cost estimation methodologies are consistent with Government guidance on the role of T&E in system acquisition (HQDA, 1997), on cost estimation (CEAC, 1997), and on economic analysis (CEAC, 1995). This chapter will show how the business case for M&S, presented in Chapter 3, can accomplish this goal. The business case approach can help illuminate the point that "M&S can be more effective and efficient when the program office develops a formal plan early in the program and secures a 'buy-in' to the plan by the acquisition decision-makers and the testing community" (Coyle, O'Bryon & Hillegas, 2000).

DTC sponsored studies to assess the benefits of using virtual testing techniques in three historical programs. The PMs of the weapon system acquisition programs would ultimately realize these benefits. The historical programs were the Enhanced Position Location Reporting System (EPLRS) (Brugh, 1997), the Automatic Chemical Agent Detector Alarm (ACADA) (Brugh, 1997), and the Abrams M1A2 Tank (Brugh, 1996) technical test programs. The focus of the studies was to estimate the actual and potential savings to cost and schedule that were achieved through the use of virtual test techniques when compared to using live test techniques.. Another DTC study estimated cost avoidance at the Simulation/Test Acceptance Facility (STAF) (Johnson, 1996). It is a goal of this thesis to apply the business case methodology developed in Chapter 3 to these previous studies to validate the need for the use of such a business case in all major decisions involving the use of M&S in developmental testing.

## **B. BUSINESS CASE APPLIED TO DT CASES**

### **1. Step 1. Baseline**

Since the key in determining the success of the selected programs lies in establishing their initial state before any changes in procedure were considered or implemented, the performance baseline measurements for the EPLRS, ACADA, M1A2 and the STAF will be addressed herein. This will be done in order to show the changes/improvements the programs underwent during the different testing events. The baseline measures were taken using live testing techniques without the use of formal M&S techniques.

The baseline objective was to compare the cost/schedule of the virtual testing with the same amount of testing using live techniques. Another major metric used for the studies was the "Number of areas assessed that are difficult/impossible to test physically

due to limitations in cost, time, manpower, or due to risk to humans, equipment, or the environment.” (Patenaude, 1996) This metric was used for all of the studied programs and was the main reason for the comparison between EPLRS I/II and EPLRS III. Cost and time would be prohibitive if human radio operators were used to obtain the required data. Other examples of this metric are Electromagnetic Interference, Nuclear Survivability, and environmental testing (Brugh, 1997). An additional metric was “Quality and quantity of test data.” (Patenaude, 1996) As might be expected, open air, live field testing with chemical agents is not practical/feasible. Chemical agent detector testing in the past has essentially always been conducted in environmentally controlled chambers; therefore, the past methodology for testing involving chemical agents was actually a “synthetic environment” in the broadest sense. The comparison was made between the cost/schedule during the ACADA Production Verification Test (PVT) using the Detector Test System (DTS) and the cost/schedule if the tests were conducted in a standard chamber. Since, the baseline should include a clear enunciation of assumptions and constraints, it should be understood that this is very difficult in the changing environment of M&S where techniques and technology opportunities are changing almost weekly. The main metric used was the “Number of areas assessed that are difficult/impossible to test physically due to limitations in cost, time, manpower, or due to risk to humans, equipment, or the environment.” (Patenaude, 1996)

## **2. Step 2. Vision/Direction**

Current force reductions have lead to restructuring. DTC, in order to continue its testing mission effectively, must downsize and restructure to test smarter with fewer resources. Current and nascent technologies are the ideal means for accomplishing this goal. DTC has a long history of using physical simulation to confirm a weapon system’s

readiness and technical maturity; presently DTC is reengineering the Army's test capability through its VPG initiative. The VPG consists of a comprehensive and interrelated set of synthetic environments, stimulators, and simulation test procedures operating within a standard architectural framework. The VPG will be used to confirm a system's readiness and technical maturity, from concept through fielding, and with a substantial reduction in program resources. Historical data from actual hardware tests on DTC ranges and other real-world test sites provide ground truth data that anchor the VPG to reality.

In order to prove the need to invest in new testing technology, DTC must prove the worth of developing a VPG on a continuous basis. The ultimate goals of VPG are to accomplish testing better, faster and cheaper. One method of proving the worth of VPG is through cost avoidance and benefit analyses. A cost avoidance methodology for VPG will be presented herein. Several studies have been conducted to show the results of some early VPG investments that benefited the testing community and the PM ultimately. The results of these studies will be used to demonstrate the validity of the cost avoidance model and the ROI.

Most of the testers who discuss this subject agree that a VPG runs much the same as a physical proving ground, except that the nature of the item being tested, the mechanisms of communication, data collection methods, and other basic functions shift toward the digital computer model. DTC has tested physical hardware and prototypes on ranges and in laboratories for decades (physical testing); the VPG extends DTC's test capability into the domain of models, virtual prototypes, and hardware-in-the-loop simulations (virtual testing).

Three testing paradigms, physical, and virtual, help one to distinguish among the paradigms and explain the realm of the virtual proving ground. Physical testing is a hardware process that yields original knowledge and experience pertaining to the functionality of the weapon system, subsystems, and components as well as the nature and effects of the natural and man-made environments (Ground Truth). Data from physical testing serves as the basis for functional and conceptual models of both the systems and the environments. Virtual testing is comprised of a mix of hardware systems, subsystems, components and/or prototypes; soldier-in-the-loop simulators; and digital models. Data collected from virtual testing is based on the system, subsystem, or component performance of the physical hardware or human in the loop simulations coupled with the modeled effects of the remainder of the system and environment. This virtual test data contains a level of uncertainty due to the assumptions and approximations used in the digital models. However, the application of a rigorous verification, validation and accreditation process can minimize this uncertainty.

Given the above basic understanding of the realm of the VPG, it is reasonable to ask how the VPG operates and who the players are. The current VPG operational players include DTC test centers, Operational Test Command (OTC), Research and Development Centers (RDECs), PMs, and contractors. After full VPG development, the players will have additional testing tools in the constructive simulation arena that will allow testing that is no longer limited to physical proving grounds or test centers. For some completely constructive testing, the concept of taking a piece of hardware to a specific physical location will no longer be relevant. DTC will still be the tester in the sense that DTC test centers will produce models of the test process, and ground truth data needed for both

producing and validating the system and environment models. This role of the virtual tester is complementary to the classic physical testing mission that is necessary to continue regardless of the sophistication of the emerging VPG. Important players are the other members of the IPT and the PMs. It is reasonable to visualize the PM office for a developmental system as the organization that links to various players to obtain the necessary testing models and other pertinent information to run a test on a system model developed at the PM's organization. For instance, running such a test involves sharing the system model and its associated test issues and criteria with the DTC agency, which tailors the model for the specific test. All of this takes place within a distributed, but connected, complex of organizations that contribute to the virtual testing process.

As mentioned above, a reasonable place to start an analysis of the VPG process is the hardware testing process. Figure 2 is a simplified diagram of the process of conducting hardware tests at fixed ranges and test centers. Basically, the process involves a physical system that is designed and manufactured to satisfy a set of critical issues and associated criteria, and tested to those issues and criteria. A set of test plans is derived from the requirements of those issues and criteria. These test plans contain the test procedures and call for specific instrumentation to obtain test data. Test resources and historical data also contribute to test plans. Tests are executed from the plans. Test outputs are in the form of test data. System assessors use the data to determine how well test issues are satisfied and criteria are met. Classically, DTC is the major player in essentially all of the boxes of this physical hardware technical testing process. This is due to the fact that the developer sends the hardware system to a DTC test center or

proving ground to be tested. Additional weapon system developer resources or equipment are often added at the test site or range to execute tests and obtain data.

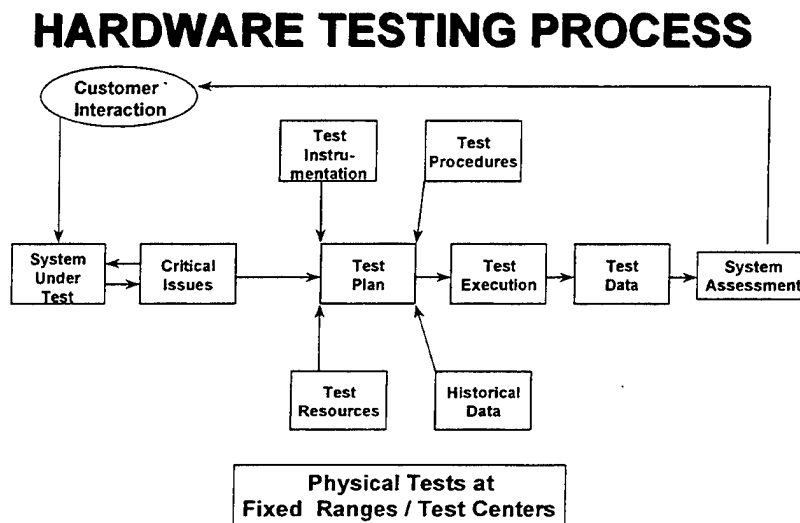


Figure 2. Hardware Testing Process. (Source: Researcher)

The virtual testing process, Figure 3, is diagrammed in much the same way as Figure 2, but differs in two basic ways. First, systems being tested and test procedures themselves tend to be in digital forms rather than physical forms. The digital form includes the virtual testing zone where humans and hardware in the loop simulations are challenged by synthetic stimuli. Second, Figure 3 follows the VPG operational concept that distributes the responsibility for testing to those organizations that are a part of the distributed VPG complex. The testing process is on the centerline of Figure 3. Support/infrastructure are shown above and below the centerline. The Internal/External Interface Infrastructure represents principally the networked electronic infrastructure that links players in the VPG testing process.



## VIRTUAL TESTING PROCESS

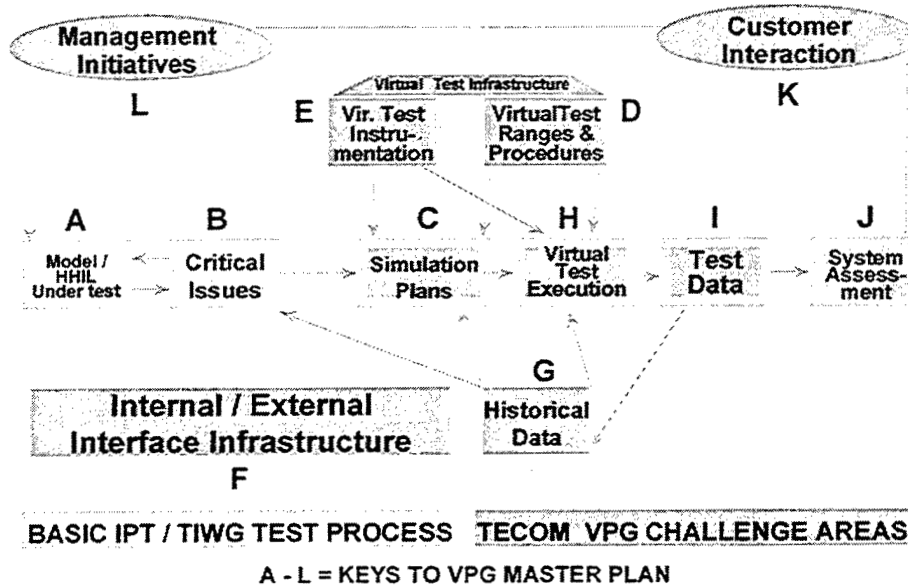


Figure 3. Virtual Testing Process. (Source: Researcher)

### 3. Step 3. Quantify the Costs and Benefits of Alternatives/Capabilities

According to the Army, the "Economic Analysis Process" (CEAC, 1995) is an eight step process: (1) Establish objective, (2) Formulate assumptions, (3) Identify constraints, (4) Identify alternatives, (5) Estimate costs and benefits for each alternative, (6) Compare alternatives, (7) Perform sensitivity analysis, and (8) Report results and recommendation. The Department of the Army Economic Analysis Manual recommends that an economic analysis study plan include the mission, background, purpose, constraints, assumptions, cost element structure, cost and benefit estimating methodology, system description, configuration, schedules, and issues. The level of economic analysis detail increases with project dollar value or project visibility. Among the limitations with economic analysis discussed in the manual are that economic analysis cannot be applied with cookbook precision, but must be tailored to fit the problem, and

that it is not a substitute for sound judgment, management, or control. The Business Case Framework outlined in detail in Chapter 3 of this thesis has all of the steps outlined by the Army and features the characteristics necessary to make a business decision to make a decision about using M&S in the discipline of testing. Therefore, the techniques for economic analysis detailed in the Business Case Framework outlined in Chapter 3 of this thesis will be used to do the analysis of the four systems.

*a. Cost Analysis Metrics*

“A true measurable metric would be any numerical value that enables us to assess how much faster, how much better, and how much cheaper a given acquisition process is or can be fielded.” (Pinker, 1997) Measurable T&E cost metrics, live or VPG, include cost of consumable items, cost of facilities, cost of technology, and test-personnel costs. Others are schedule with consideration for acquisition phase time, administrative lead-time, and of course test time. Developmental T&E affect program cost through knowledge of performance and the design changes necessary to implement a system that does not meet requirements. Developmental T&E provide benefits in troubleshooting and data requirements generation.

These and other metrics may apply to cost savings, cost avoidance and productivity improvements. Cost savings result in the reduction of cost of approved budget items. A cost avoidance is the result of an action taken in the immediate time frame that will decrease cost in the future. For example, investment in a test technology that decreases the test cost while increasing risk reduction is a cost avoidance action. A productivity improvement is a reduction in future personnel time and effort requirements associated with a function or assigned task that has been included in an approved

program. Under normal circumstances, productivity improvements do not represent an opportunity to reduce an approved program, budget or force structure. Unlike cost avoidance, productivity improvements have no direct impact on future requirements for funding, but enable accomplishment of more work with existing personnel. Productivity improvements can accrue at any time during the life cycle.

***b. Cost Estimation Approaches***

With a description of the process, contents and metrics for cost estimation, the analyst must select an approach. "The engineering approach, parametric approach, analogy approach, and expert opinion approach are four cost-estimating methods. The use of a specific approach varies with the reliability and quantity of available data. Each approach has limitations." (CEAC, 1997)

The engineering (bottom-up) approach is an examination of separate work segments in detail and a synthesis of the many detailed estimates into a total. With this approach, the analyst divides the system, activity, or item of hardware into its segments and makes an estimate of each segment's costs. The analyst then combines these estimated costs with estimates of integration costs to arrive at a total cost. A major limitation of the engineering approach is that it requires the analyst to have an extensive knowledge of the system, activity, or item. Also, the analyst must know both the development and production processes. Particularly for new technologies, the detailed knowledge required for a complete engineering analysis is not always available, making this approach the most difficult to apply. (CEAC, 1997) Since the technologies are known for the EPLRS, ACADA, and Abrams M1A2 historical studies the engineering approach was used in the analysis.

The benefit estimating process is similar to that for cost estimating. Data must be collected from appropriate sources and analyzed; relationships among data must be identified. Inflation and discounting must be applied to annual dollar values via standard methods; the economic life of the alternatives and the fiscal years when benefits accrue must be carefully considered. Once benefits have been calculated, savings must be separated from cost avoidance and productivity improvements.

*c. VPG Considerations*

In the VPG cost estimating methodology, DTC wishes to separate operating costs from fixed or investment costs. The total cost of the current alternative = Fixed Costs( $F_a$ ) + Variable Costs ( $V_a$ ). DTC wishes to make cost estimates for the PMs. The fixed cost to the PM may be zero if an acquisition program can use a maintained facility developed by a predecessor program, or new capability is developed by DTC. For virtual testing, the fixed cost is usually an investment in the model, simulator or stimulator. The Investment Cost, a nonrecurring cost, includes land, building, machinery and equipment. Operating Cost, or recurring cost includes personnel, maintenance, and materiel/supplies.  $F_a$  includes instrumentation development cost, and facility development cost (materials and labor).  $V_a$  includes labor, expendables, and maintenance and test preparation/planning.

Cost estimates for the VPG are complicated due to the cost estimation of software development. "Because software life cycle costs account for a significant portion of information systems' costs, and are often significant in materiel systems, they must be estimated carefully. Software cost estimating involves a large degree of professional judgment, from both a project management and cost analysis perspective."

(CEAC, 1997) To the extent that each program requires a degree of VPG ongoing software and technology development, the cost estimating process requires care.

Since one of the motivations behind doing virtual testing is accomplishing testing faster and cheaper, a cost avoidance methodology would help define the benefits associated with this new testing paradigm. Based on the previous sections that help define what physical and virtual testing involve, a cost avoidance methodology can be developed. In order to develop a VPG cost avoidance methodology, the basic steps for economic analysis must be considered. The Seven Steps for Economic Analysis include: establish and define goals and objectives, formulate assumptions and identify constraints, identify alternatives for meeting objectives, determine inputs and outputs of each alternative, compare cost and benefits of alternatives, evaluate and determine the risk and uncertainties, prepare conclusion and recommendation. For this effort the focus will be to compare the cost and benefits of alternatives.

When performing a benefit analysis, all significant benefits must be included whether quantifiable or non-quantifiable. Benefits, which cannot be quantified, should be described in narrative form. Every effort should be made to quantify benefits to the maximum extent possible. A sample of some benefits to PMs, testers and evaluators using M&S include: performing the mission with fewer test items, increased understanding of simulation technology, supporting safety and environmental assessments, preventing false starts by performing test rehearsals, better understanding of how the components/subsystems/systems under test are designed to function in an integrated fashion, more confidence in data due to verification by simulation, and providing a test diagnostic capability. Some of the benefits of using M&S to the

customer or Program Manager include: fewer test items, lower test costs, reduction in test time, early knowledge of test environment models, powerful tool for data analysis and trouble shooting, improved data requirements generation, and validation of component/system models. Once the benefits have been identified, then the benefits are subdivided into those that are dollar quantifiable and those that are quantifiable in other terms.

The benefit estimating process is similar to that for cost estimating. Data must be collected from appropriate sources and analyzed; relationships among data must be identified; inflation and discounting must be applied to annual dollar values via standard methods; the economic life of the alternatives and the fiscal years when benefits accrue must be carefully considered. Once benefits have been calculated, savings must be separated from cost avoidances and productivity improvements.

The three categories of quantifiable benefits include cost savings, cost avoidance and productivity improvements. A cost savings results in the reduction of an approved program. The item under consideration must be part of an approved budget. A cost avoidance is the result of an action taken in the immediate time frame that will decrease cost in the future. For example, an engineering improvement that increases the mean time between failures and thereby decreases operation and maintenance costs is a cost avoidance action. A productivity improvement is a reduction in future personnel time and effort requirements associated with a function or assigned task that has been included in an approved program. Under normal circumstances, productivity improvements do not represent an opportunity to reduce an approved program, budget or force structure. Unlike cost avoidances, productivity improvements have no direct

impact on future requirements for funding, but enable accomplishment of more work with existing personnel. Productivity improvements can accrue at any time during the life cycle. Following is a cost avoidance methodology developed to support the cost avoidance activities of the VPG for test articles as well as test resources.

The developed VPG cost avoidance methodology uses a comparison analysis between the cost of the current alternative and the cost of the simulation alternative. This is similar to the business savings calculation in Figure 1 (Benefit Cost Calculations).

Total Cost of Current Alternative (physical testing) = Fixed Costs ( $F_a$ ) + Variable Costs ( $V_a$ ); where the fixed cost may be zero. Total Cost for Simulation Alternative (virtual testing) = Fixed Costs ( $F_b$ ) + Variable Costs ( $V_b$ ); where the fixed cost is usually an investment. Cost Avoidance = Total Cost of Current Alternative - Total Cost for Simulation Alternative.

Where:

- Investment Cost (Nonrecurring cost) – Land, building, machinery, equipment and software.
- Operating Cost (recurring cost) – Personnel, maintenance/updates (hardware and software), and materiel/supplies.
- $F_a$  – Instrumentation Development Cost, Facility development cost (materials and labor).
- $V_a$  – Labor, expendables, maintenance and test preparation/planning.
- $F_b$  – Simulation development/modification, instrumentation development, HWIL simulation facility development.
- $V_b$  – Labor for test execution, expendables, hardware and software/simulation maintenance, test preparation/planning.

If the overall objective is to field faster, better, and cheaper weapon systems, then a true measurable metric would be any numerical value that enables us to

assess how much faster, how much better, and how much cheaper a given acquisition process is or can be. Some quantifiable measurable metrics are noted herein.

- Cost with consideration for the consumable item price index and military specification conversion price benefit.
- Schedule with consideration for the acquisition phase time, administrative lead time and test time.
- Program cost with consideration for change in program cost as a consequence of changed acquisition processes.
- Unit Life-Cycle Cost considering change in projected unit life-cycle cost as a consequence of changed acquisition process.
- Operational performance versus cost with consideration for the comparison of operational test results versus specified performance.
- Cost of Performance considering the kind of system performance that can be bought for a given cost. To derive this metric it would be necessary in some way to quantify various combinations of system performance.
- Cost as an independent variable is savings in a program where costs are held constant and performance and schedule are adjusted.

The primary metrics used in the following studies considered were cost and schedule even though others could be considered for future analysis.

#### **4. Step 4. Evaluate Alternatives**

##### ***a. Analysis of Historical Programs***

Where possible, the live test equivalent to a virtual test procedure was chosen or designed to provide the same level of risk reduction. It is not assumed that test money is limitless. Thus, if the live test design produced an unreasonable test cost, a reduced-scope live test was used for comparison, with an attendant increased technical risk. Labor costs are normalized to the same year, and not broken down by skill levels. There is a factor for inflation. The cost of facilities may be paid with DTC institutional funding.



*b. Enhanced Position Location Reporting System Study*

The EPLRS Technical Test III (TT III) was conducted at the US Army Electronic Proving Ground (EPG), Fort Huachuca, AZ. A series of EPLRS tests (TT I and TT II) were conducted five years prior to TT III, using live testing (i.e., human radio operators/data collectors). The methodology used was to calculate the additional resources required, for the same number of test days (75) during TT III, using TT II (labor intensive) methods.

The TT I/II test consisted of an average of 160 radio sets (RSs) distributed at various locations in an area of 400 km<sup>2</sup> and required over 300 operators/data collectors. There was limited automated data collection. Test-scenario-control was by hand-held FM radio, and required extensive logistics support for the operators. All of the equipment at each site was installed and removed daily for security purposes, which lengthened the test day by about four hours. Data consolidation, reduction, and analysis normally took about five days.

During TT III many time/cost-saving automated tools and methods for control, monitoring, and data collection were used. Elements contributing to cost avoidance were: less logistics support; number of operators; a Test Control Center (TCC), use of a Personal Computer (PC) as a Test Item Stimulator (TIS); and security/test sheds with alarms to house the equipment. The TCC, with automated data collection, reduced analysis time from five days to one. Each of the average of 120 sheds held a PC/TIS, the EPLRS, a packet radio for communications between the TIS and the TCC, and the alarm. In effect, the self-contained sheds with the TIS were a "virtual

workforce" that replaced the human operators/data collectors. Shed support consisted of exchanging batteries, turning on/off equipment, TIS data dump, and on-call maintenance.

The original study (Brugh, 1997 A) assumed that the TCC, sheds, and automated data reduction tools were not available. Daily setup and tear down increased the workday by two hours and required large trailers for equipment storage. Support personnel increased by 50% from 69, plus 120 operators. Transport vehicles carried six testers and test equipment. One instructor was required per group of 16 to provide three days of training to military and civilian operators. The analysis constrained the test cost at \$10M maximum, and assumed a civilian/military mix of testers to be 115/40. Civilian labor was \$32/hr and military labor was free to the customer. The analysis did not consider the test center's investment in PCs, packet radios, automated data collection software, and the cost of the TCC.

The additional resource cost for 75 test days was \$2.2M labor + \$0.8M overtime + \$0.1M equipment, and fixed costs of \$0.1M training + \$0.03 M equipment for a total \$3.2M. Since the TT III cost \$6.3M as conducted, the \$10M spending limit would be nearly reached (\$3.2M + \$6.3M) during the 75 test days of labor intensive testing. Expert opinion was (Brugh, 1997) that only one-third to one-half the amount of usable, high-quality data would be acquired during the 75 test days with this method. Another alternative to the earlier study allows use of the sheds, which would avoid the overtime costs. This still results in a \$2.4M cost avoidance for the VPG stimulator technology.

Using the VPG cost avoidance methodology presented previously, the following summaries can be made. The cost of the EPLRS TT I/II is \$10.085M. The cost of the EPLRS TT III is \$7.233M. Both test cost amounts have been adjusted to 1993

base year dollars. These figures were obtained by totaling the fixed costs of facilities and instrumentation and variable costs of vehicles, hand held radios and labor. Subtracting the cost of the virtual test from the physical test, the cost avoidance is \$2.852M. The following savings, which used an estimated test costing analysis, were stated in the study: "EPLRS Savings as tested: Virtual testing during TT III, saved the EPLRS program \$3.2 million, provided many millions of dollars worth of risk mitigating and risk management information, and shortened testing by a minimum of 75 days." (Brugh, 1996) Using the VPG cost avoidance methodology produces numbers that are marginally close to those stated in the study. See the test methodology comparison in Table 3.

	Human in the Loop	Test Item Stimulator	
Required Personnel	155	69	
Test Days Avoided	0	75	
Cost To Test \$	\$10.085M	\$7.233M	Cost Avoidance \$2.852M

Table 3. EPLRS Test Methodology Comparison. (Source: Researcher)

In summary, virtual testing during TT III resulted in substantial cost avoidance, \$2.4M - \$3.2M, and significantly increased quality and quantity of data, vice use of less VPG-intensive technologies.

*c. Advanced Chemical Agent Detector Alarm Study*

The chemical/biological defense case study was on the ACADA PVT at Dugway Proving Ground, UT. As might be expected, open air, live field-testing with

chemical agents is neither practical nor feasible. Chemical agent detector testing in the past has essentially always been conducted in environmentally controlled chambers, or using simulants in lieu of live agents (i.e., virtual testing). Previous testing was conducted in Building 3445, the large chamber facility. While the large chamber can accommodate testing of large vehicles and equipment, testing of small agent detectors required construction of a smaller chamber inside the large facility. Past testing indicated that an earlier small chamber design could simultaneously test only two detectors of the six for which it was designed. The number of support personnel for Building 3445 is fourteen. For the ACADA PVT, a new stand-alone, HWIL test facility (the Detector Test System, DTS) capable of testing twelve detectors simultaneously, and requiring only five testers, was developed. The customer contributed to the fixed-cost of construction of the DTS (\$82,200 of a total cost of \$421,000). Twelve detectors were tested simultaneously for 39 days in Phase I, eight for 92 days during Phase II.

The study objective (Brugh, 1997) was to estimate cost for Phase I Agent Testing and Phase II Agent/Simulant testing during the ACADA PVT, using the DTS and using Building 3445. Testing using a corrected six detector chamber design was not considered.

The study assumptions (Brugh, 1997) were as follows. Each tester costs \$355 per ten-hour day. The times required to startup, conduct and shut down a trial are the same in both facilities. The PM had no fixed facility-usage cost and no cost for construction of a small chamber in Building 3445. Test equipment reliabilities are the same in both cases.

The operating cost is the number of people who run the facility multiplied by the personnel cost per day, multiplied by the number of test days. For phase I, the cost is \$.065M. The corresponding Building 3445 cost would be greater by factors of 14/5 (personnel) and 12/2 (detectors) to total \$1.1M. For Phase II, the 92-day cost was \$.154M. The corresponding Building 3445 cost would be greater by factors of 14/5 (personnel) and 8/2 (detectors) or \$1.7M.

The variable cost totals are (Cost Phase I + Cost Phase II), \$.219M for the DTS and \$2.8M for Building 3445. The total cost to the PM, fixed plus variable, was \$.302M for the DTS. The test schedule would increase from 131 days for the DTS to, in Building 3445, 602 days. For this study, we add an alternative scenario that assumes correction of the earlier design to allow simultaneous measurement of six detectors in Building 3445. This results in \$.364M variable Phase I costs and \$.575M in Phase II, or \$.939M total cost. Schedule would be 201 test days. Investment in the DTS resulted in substantial cost avoidance to the customer even for this technically unsubstantiated scenario.

The objective of the ACADA study was to compare the cost and schedule of the virtual testing during the ACADA Production Verification Testing, with the same amount of testing using previous testing techniques. As one would expect, live open air testing with chemical agents is not practical or feasible. Chemical agent detector testing in the past has essentially always been conducted in environmentally controlled chambers. This technique is essentially virtual testing. The comparison was made between the cost and schedule during the ACADA production verification testing using the DTS and the cost and schedule if the same tests had been conducted using the

Chemical Agent Monitor test configuration. The DTS, which uses more automated simulation techniques, will be considered the virtual testing method. The testing completed using Chemical Agent Monitor test configuration will be considered the physical testing technique. The factors considered when conducting a cost and schedule analysis of the two testing techniques include: number of personnel required to conduct testing, number of items which can be tested simultaneously, time required for test setup, and facility costs (procurement, setup, and sustaining).

Again, using the cost avoidance methodology presented previously, the following summaries can be made. The cost of the ACADA test using the Detector Test System is \$.302M. This figure was calculated using the fixed cost of developing the Detector Test System and the variable cost of labor. The cost of the ACADA test, if conducted using the Chemical Agent Monitor test configuration, would be \$2.823M. This amount was calculated using the variable cost of labor for running a test using the Chemical Agent Monitor test configuration. Subtracting the cost of the virtual test from the physical test, the cost avoidance is \$2.521M. The following savings, which used an estimated test costing analysis, were stated in the study: "ACADA Savings as Tested: Virtual testing during Production Verification Testing, saved the ACADA program \$2.5 Million and shortened testing by 471 days." (Brugh, 1997). The numbers for cost savings stated in the ACADA study matched the numbers for the calculations using the VPG cost avoidance methodology. The \$2.5 Million cost savings stated in the study are actually cost avoidance dollars by definition. See the test methodology comparison in Table 4.

	Chemical Agent Monitor Test	Detector Test Set	
Detectors Tested	2	12	
Test Days	602	131	
Cost To Test \$	\$2.823M	\$.302M	Cost Avoidance \$2.521M

Table 4. ACADA Test Methodology Comparison. (Source: Researcher)

The results were substantial cost avoidance, \$2.6M, and schedule avoidance, 471 test days, from investment in the newer simulation technology vice usage the existing old technology.

*d. Abrams M1A2 Tank Study*

This study (Brugh, 1996) identified use of virtual testing during the Production Qualification Test (PQT) program and during the live fire testing at Aberdeen Test Center (ATC). Seven PQT tests at ATC and two at the White Sands Missile Range (WSMR) used virtual testing that resulted in cost avoidance. The WSMR Electromagnetic Environmental Effects test and Nuclear Effects test had no feasible live test alternative and therefore did not involve cost avoidance, but did result in risk reduction. For this work, only the accuracy test will be addressed.

Within the accuracy test description, the first letter indicates tank motion and the second indicates target motion to be stationary (S) or moving (M). S/M, M/M, and M/S at Aberdeen Test Center's Trench Warfare I (TW I), with targets simulated by laser, each costs 15 testers @ \$400/tester/day (10 hr) for 22 days, or \$.132M. Non-Firing Tracking M/M (NFT M/M) costs 10 testers @ \$400/tester/day for 8 days or \$.032M. The

total labor cost on TW I is \$.428M. Expert opinion indicates that physical target simulators require at least twice as many days to collect the required data and two additional testers. A daily target cost of \$500/target/day would accrue for the S/M, M/M, M/M NFT scenarios. For the S/M and M/M tests, the cost would be \$.321M. The M/S cost is the same (\$.132M). The M/M NFT cost would be \$.085M. The total cost, labor and targets of the physical simulation tests are \$.859M. The difference (S/M, M/M, M/S and M/M NFT) of labor and targets is \$.431M. See the test methodology comparison in Table 5.

	Physical Target	Laser Target	
Projectiles Saved	0	2580	
Test Days Avoided	0	258	
Cost To Test \$	\$.859M	\$.428M	Cost Avoidance \$4.8M

Table 5. Abrams M1A2 Test Methodology Comparison. (Source: Researcher)

For S/S at Trench Warfare II, there was a requirement for measuring accuracy at four distances. Prior to TW II construction, firing projectiles at each of the required distances met the requirement. At TW II, virtual video "scoring" at the four distances, for a projectile fired at the longest distance, reduced by 75% the number of projectiles and the test time. This avoided almost \$3M in the cost of ammunition alone, with added labor reduction of nearly \$1M. The total cost avoidance by using virtual testing during the accuracy testing was \$4.4M. Other virtual fire control tests brought the



total cost avoidance to \$4.8M, a schedule reduction of 258 days, and 2580 projectiles not fired.

*e. Simulation/Test Acceptance Facility (STAF)*

The STAF is a HWIL facility at the Redstone Technical Test Center (RTTC) in Huntsville, AL that greatly reduces the number of destructive live flights of missiles in production flight-testing and in stockpile testing. Completed missiles containing tactical seekers, guidance electronics, inertial navigation systems, warheads, squibs, motor, and control actuators are tested in a remotely controlled bunker. With the motor and warhead circuits disconnected, the missile flight dynamics are simulated using a six degree of freedom digital model of the missile's airframe running in real time. The facility can modulate radio frequency signals to present realistic in-band representations of complex targets to the millimeter wave seeker or realistic InfraRed (IR) signals to an IR seeker. A real-time data collection system records data from simulated launch to simulated target impact. Missiles are consumed only to test motors and warheads, and as model validation. Rounds tested in the facility can be returned to the inventory. Separate cost estimates (Johnson, 1996), not repeated for this work, indicate that the STAF with RF representation cost \$6M. Typical live firing lot acceptance testing costs customers approximately \$9.5M/year. The same testing conducted in the STAF costs approximately \$1.5M/year for cost savings of \$8M/year.

*f. VPG Cost Avoidance*

The chart shown below summarizes the VPG cost avoidance to the customer through use of M&S to support the four acquisition programs addressed in this thesis. .

## VPG COST AVOIDANCE (\$M)

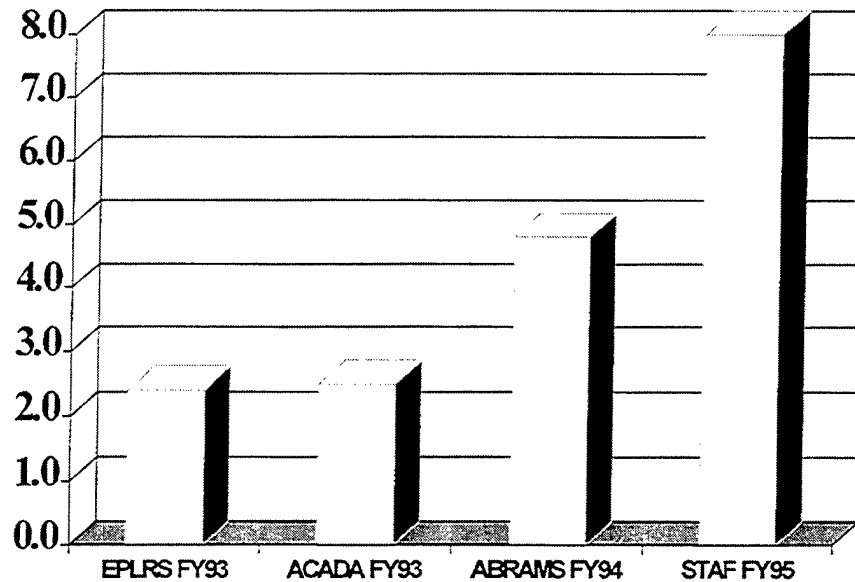


Figure 4. VPG Cost Avoidance. (Source: Researcher)

### 5. Step 5. Conduct Sensitivity Analysis

The STAF facility was the only program that performed a detailed sensitivity analysis. The Air to Ground Missile System (AGMS) Project Office and DTC RTTC performed an analysis of the perspective factors and trade-offs involved in implementing a HWIL lot acceptance program versus a traditional Fly-to-Buy (FTB) program. This analysis considered the two alternatives available to Longbow Hellfire (LBHF), as well as, the historical data provided by the earlier HELLFIRE I. The primary factors in the development of the assumptions involved in this analysis process were as follows:

- Unit Costs:
  - HELLFIRE cost per missile \$ 20k.
  - LBHF cost per missile \$ 300k @ Low Rate Initial Production (LRIP).
- Test Programs:

- HELLFIRE and LBHF Lot Acceptance Testing: FTB @ 4-10 missiles per month.
- LBHF HWIL Simulation: 4 live fires per year and up to 20 missiles simulated flight testing per month.
- Facilities: Facility for the HWIL Simulation: \$ 5.8 million. The building and instrumentation.
- Labor: Personnel needed to run this facility for one year: estimated at approximately \$0.8 million.

With these factors in mind, a trade-off analysis was performed using costs for four missiles with the results portrayed in Table 2. The total savings projected under a HWIL simulation lot acceptance test program would represent cost savings of \$7.78 million per year over a conventional FTB program. Even including the \$5.8 million necessary for developing the HWIL simulation facility, the payback period under this assumption would be less than one year.

<p><b> LONGBOW</b></p> <p><b> Lot Acceptance Methodology</b></p> <p><b> Cost Tradeoff</b></p> <p><b> (Post Cost Reduction Program)</b></p>			
	<p><b> BASIC HF</b></p> <p><b> FTB</b></p>	<p><b> LB HF</b></p> <p><b> FTB</b></p> <p><b> (What if)</b></p>	<p><b> SIMULATED</b></p> <p><b> PROGRAM</b></p>
MISSILE COST	\$1.15 MIL	\$8.11 MIL	\$0.68 MIL
EGLIN SUPPORT	\$0.72 MIL	\$0.72 MIL	\$0.06 MIL
RTTC SUPPORT	\$0.53 MIL	\$0.53 MIL	\$0.44 MIL
SYS. SIM. SUPPORT	\$0	\$0	\$0.40 MIL
TOTAL	\$2.40 MIL	\$9.36 MIL	\$1.58 MIL
SAVINGS = \$9.36 MIL		NONRECURRING FACILITY COSTS:	
	- \$1.58 MIL	Total Facility Cost:	PM-ITTS \$1,000K
	\$7.78 MIL PER YEAR		other \$330K
PAYBACK PERIOD << 1 YEAR			AGMS-PMO \$4,500K
			\$5,830K

Table 2. Longbow Lot Acceptance Methodology Cost Tradeoff. (Johnson, 1996)

The Basic Hellfire (HF) FTB column indicates approximately what AGMS pays per year for the HELLFIRE I FTB program, and also indicates where the true cost growth in FTB actually lies, namely, missile cost. This total amount includes missile cost, range support, and pre-flight support. The LBHF FTB column indicates what the cost would be if the AGMS Office implemented a similar FTB program with just four missiles per month. The tremendous yearly cost avoidance is due to the non-destructive nature of the simulated flights, which allows the rounds to be placed in inventory upon test completion. The analysis indicates a facility cost payback period of much less than one year.

To determine an annual return on investment for the STAF facility, the ROI formula in Chapter 3 of this thesis was used.  $ROI = \text{cash inflow (Benefit)} / \text{net investment}$ . To account for the test and simulation environment the ROI formula was rephrased as follows:  $ROI = \text{test/simulation workload} / \text{fixed cost of facility and instrumentation}$ . So, for the STAF facility the  $ROI = (4 \text{ live fires \& } 20 \text{ missiles/month for 12 months}) / \text{facility and instrumentation costs} = \$1.58 \text{ M} / \$5.8 \text{ M} = .2724$ . This represents the annual ROI for the STAF facility.

## **6. Step 6. Develop a Migration Strategy**

Of the four VPG projects examined in this thesis, only the use of the STAF facility was fully integrated into its associated acquisition program. The STAF facility is an integral part of the lot acceptance program for the Longbow missile. Unfortunately, formalized management goals and a systematic approach to capturing the expected benefits of the program were not developed. Based on this lack of formalized goals, the

monitoring and feedback process is limited to the future possibilities for use of this technology for program savings in general.

**7. Step 7. Monitoring the Process and Assessing Results through Formalized Feedback**

Other Army programs have been approached about using the STAF facility on a time-sharing basis and using HWIL simulation to reduce testing costs. The key factor here is the need to highlight the necessity of early planning to accomplish this task. LBHF has already demonstrated that it is much easier to design features into the missile that lend themselves to aiding the ease of HWIL testing, than attempting to correct these after the missile design has been locked in. In the case of LBHF, the move to HWIL simulation meant determining an after the fact means to attach the simulation hook up cable through a sealed access panel in the missile body. In addition numerous signal and interface problems and modifications were needed. These requirements would have been easier to resolve if they had been included in the original system design to accommodate a HWIL approach. Future systems should investigate this area during the design phase, so those HWIL critical features can be incorporated into the design.

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## **V. CONCLUSIONS AND RECOMMENDATIONS**

### **A. CONCLUSIONS**

The management of acquisition programs is one of the most difficult jobs in the DoD today. When making complex technological decisions where there are a limited number of variables but a near limitless combination, using a business case can help the decision-maker see through the fog. M&S allow the PM to experiment with a larger number of possibilities without undue risk and the T&E practitioner more opportunities to provide better testing at a lower cost and schedule. Once the essential data is determined, collected, and then shaped within a model, the simulations provide a tremendous advantage over traditional methods of trial and error.

The use of M&S is no longer reserved for programs on the cutting edge of technological development, but rather it is standard practice. Since M&S is a part of everyday practice, both industry and the Government should rely on sound business practices to ensure the successful application of M&S. Based on the fact that M&S is an established business tool, M&S investment justification should be based on a reasoned cost benefit analysis.

Establishing these cost benefit relationships can however be just as difficult as the management of a program itself. The use of the business case process contained in this thesis to justify M&S development provides a flexible yet structured methodology for decision-makers to weigh alternatives. This business case analysis permits the decision-maker to justify investment decisions based on cash flow analyses, as a function of externally imposed constraints, and risk reduction. Additionally, the business case allows

the capture of not only those costs and benefits that are internally quantifiable but also those that are non-quantifiable with respect to the potential benefits that may exist external to the program.

When the business case was applied to four developmental testing historical cases, some poignant discoveries were made. When a structured, disciplined process as outlined in this thesis was applied to the Enhanced Position Location Report System (EPLRS), Advanced Chemical Agent Detector Alarm (ACADA), ABRAMS M1A2 and the Simulation Test Acceptance Facility (STAF) facility study data, many inadequacies were observed. Of the four cases analyzed, the STAF facility was the closest to using a business-oriented analysis.

The initial baseline step of the business case process proved to be limited in the definition of metrics. These performance measures for the four cases were primarily limited to test time and test cost (equipment and labor). There was no clear statement of assumptions and constraints. The baseline did however address areas that were impossible or difficult to test physically. This initial step in the business case vividly displayed that there truly was no structured planning for the development of these test and simulation technologies.

The vision and direction step of the business case process is marginally well developed by the Virtual Proving Ground Master Plan. This plan however does not establish any performance criteria or measures and there are no definite goals that are tied directly to any funding. Additionally, the plan is very high level in nature without any specific implementation mechanism or projects. The plan does set the vision for using M&S to transform developmental testing.



The steps of the business case that quantify the costs and benefits of alternatives and perform the analysis showed that a cost benefit analysis was performed in order to make the original decision to develop the STAF facility. Unfortunately, the other three cases did not perform a documented cost benefit analysis. In the case of the EPLRS, ACADA and the ABRAMS M1A2, it was assumed that M&S must be used due to policy mandates and technology advances. The use of M&S in the EPLRS testing provided documented personnel multiplication factors that resulted in a test time reduction. The ACADA case used M&S where physical testing was not possible. Additionally, using M&S to test the ACADA proved to increase the number of units that could be tested simultaneously with fewer personnel. The ABRAMS M1A2 testing using simulation provided a cost avoidance for the quantity of personnel required, a reduction in test time and savings from not firing as much live ammunition. The VPG cost avoidance estimated for these programs are EPLRS \$2.4M, ACADA \$2.6M, ABRAMS M1A2 \$4.8M and realized for the STAF \$8M. Other tangible benefits include: EPLRS shortened testing by 75 days, ACADA avoided 471 test days, ABRAMS M1A2 realized a schedule reduction of 258 days, and the STAF facility realized a facility payback period of one year. The STAF facility enables all of the live missiles tested to be put back in the inventory due to its non-destructive methods. Additionally, the STAF facility is able to test missiles under more rigorous and controlled conditions with fewer resources in less time than typical live firing programs.

The conduct sensitivity analysis step of the business case showed that the STAF facility was the only case that used any type of sensitivity analysis to determine courses

of action. This step is critical to comparing the options and making a good business decision.

The migration strategy development step of the business case is where the implementation plan is developed to enable the technology or project to be integrated into the acquisition program. This implementation plan needs to incorporate a systematic approach to ensure the developer implements the identified drivers and captures the expected benefits to be assessed at the post implementation review. Of the four projects analyzed, the STAF facility was the only project that was fully integrated into its associated acquisition program from inception. The methodology with virtual targets used in the Abrams M1A2 example is now fully integrated into all fire control testing for combat vehicles which is a test process integration. This type of test process integration is a goal of the Virtual Proving Ground. The use of the STAF facility to perform lot acceptance testing of future missile lots continues to be integral to success of the Longbow missile program. This integration was planned during the early design stages of the missile program. This early integration enabled and ensured that the STAF facility would successfully support the Longbow program. Additionally, the benefits of the implementation and the integration of the facility with the acquisition program are continually being tracked for future development of a STAF facility that supports other missile sensor technologies. The early planning and migration of the STAF facility has ensured its success and the future of the HWIL technology implementations for new programs.

A whole generation of future tactical and operational level missile systems could all benefit from this type of lot acceptance testing. The major concern here is that these

systems need to make decisions about simulation testing now while still in their developmental stages. It has already been discovered that as these systems increase in complexity, the need to design in access and compatibility with simulation testing up front is crucial. Delaying this activity will only create additional design, interface, and cost problems. The future of testing will use simulation assets that will provide benefit to acquisition programs. This benefit can only be realized through proper early planning in the design of both development and testing systems. For example, this could be achieved by providing high fidelity system simulations early on for testing.

The monitoring and feedback step of the business case, Step 7, is intended to monitor and assess the project's progress towards the overall vision. The STAF facility is the only project that has monitored their process, determined ways to improve the process and then continued towards developing future facilities based on their concepts for using HWIL technologies to improve the testing capabilities of an acquisition program. By making an investment in current and future testing technology and applying it today, avoidance in testing costs and resources can be realized using virtual testing techniques.

## **B. RECOMMENDATIONS**

Having a clear understanding of the state of development, the following recommendations will serve to assist decision-makers with the development of M&S investment strategies based on a sound business case development processes.

PMs must be encouraged to add discipline and structure to their M&S justification process. Service leadership must challenge PMs to use a business case development

methodology to support M&S investment decisions. Decision-makers and their staff need adequate training in order to properly implement business case-based M&S investment strategy justification. Additionally, training in the development of strategic management techniques and practices would ensure that the vision step of the business case strategy is developed from an issue perspective with realistic objectives.

When implementing the business case process, I recommend several points be kept in mind to ensure success. Detailed baselines must be developed with future data collection efforts in mind. The assumptions should include estimated future workload, useful life of the investment, and the period of time over which alternatives will be compared. The data collection activities will be used to justify and compare programs properly. Additionally, metrics to be used throughout the program should be realistic and tied to the program visions and goals. Total Ownership Cost (TOC) must be addressed more rigorously for all programs from concept through disposal. Too often TOC is ignored or inadequately addressed during the analysis. Rigorous reviews of the M&S effort must be performed throughout the program with continuous feedback to all elements of the program being developed and the process outputs recorded for the benefit of future development programs. The output of the Post Implementation Review (PIR) should feed into annual performance plans which will support the vision and direction set forth in the master or strategic plan developed. The annual performance plans should show how all of the functional requirements and the feasibility of the cost and benefits of the alternative will be tied to program schedules and budgets.

Future VPG program and project efforts need to be based on a detailed plan which is embraced by all levels of management, which is supported by an annual performance

plan, and outlines the metrics by which the individual projects will be assessed. The performance plan should tie all project requirements to a funding line in the budget. All future major VPG projects which support the development of the DTC stand-alone capability and those that are tied to acquisition programs should be required to follow the business case analysis contained herein to ensure that the development effort is cost effective and meets the technical and business goals of DTC.

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## APPENDIX A. M&S AND CONTRIBUTING WORLD TECHNOLOGY EVENTS

Year	M&S and Contributing World Technology Events (In Chronological Order)
1867	Rigid Kriegspiel
1917	Ruggles Orientator
1918	Sand Tables
1920 thru	Tactical Research (Lindell Hart)
1930	First Link Trainer
1930 thru 1940	Wargames at Naval War College
	Navy Buys Instrumented Trainer (\$1500)
	Army Buys 6 link trainers @ \$3500 each
	German Soldiers stand guard with broom sticks simulating rifles
	Turing describes "universal machine"
1940 thru 1950	Louisiana Maneuvers
	Bletchley Park
	University of Illinois Aviation Lab
	Colossus Computing Machine (cryptography)
	Eniac (University of Pennsylvania)
	LINK Founded
	Whirlwind Digital computer
	Operations Research Formalized – Eisenhower Letter
	Transistor Patented
1950 thru 1960	Contact Analog Display (George Hoover, USN)
	Link begins development of first simulator for fighter aircraft
	AAI and Texas Instruments Founded
	Flat See through display for aircraft
	ILLIAC (University of Illinois)
	First commercially available computer (Univac 1)
	Live/Virtual Simulations of Air Defense
	FAA Air Traffic Control Center for Simulations (FAA/RAND/SDC)
	First COEAs
	TI Produces Silicon Transistor
	Navy disposes of WWII aircraft – Generally Trainers
	DEC Founded
	FORTRAN
	SAGE System
	Kwajalein Test Site Selection
	Minsky & McCarthy form AI Department at MIT

	First Mini Computer PDP-1
	LISP 1.5
1960 thru 1970	First Triangulated Irregular Networked Terrain
	IBM 7070
	ALGOL 60
	Line of Sight Algorithms
	NATO Range Study
	Lockheed Combat Model
	Carmonette Development
	Early Digital Terrain
	Teletype Model 33 with Punched Paper tape
	Simsript (RAND)
	FORTTRAN IV
	Model Board Visual Systems
	Image Generator for NASA Docking Simulation (GE)
	Navy Transfers Kwajalein to Army
	First Mouse
	BASIC
	Lunar Lander Simulation (GE)
	TACOS Model (Air Defense)
	First Commercial Nuclear Power Plant Simulation (Indian Point)
	First Head Mounted Display (Ivan Sutherland)
	Evans & Sutherland Founded
	SIMULA
	Computer Image Generator (CIG) for Navy (GE)
	First Laser Application for Direct Fire Weapons
	Dyntacs Development
	Land Combat Systems Study LCS-90 using Carmonette
	AF Human Resources Lab Aircrew Research Established
	SAIC Founded
	ARPA Begins Development of ARPANET
1970 thru 1980	First Advanced Simulator for Undergraduate Pilot
	First Non-Realtime Demo of CIG Potential for Airline Training (Hancock Airport)
	Navy Establishes Top Gun
	SEL 86
	Air Combat Maneuvering Range and Instrumentation (ACMR/ACMI)
	AMC 71 Ground Mobility Model
	TACWARS Development Begins
	Royal Navy School of Training Established
	Intel Founded
	ATOWL Mission Planning Software
	TETAM Intervisibility Experiment



	LCOM (TAC/LOG Manning)
	First Micro Processor Chip (Intel 4004 60,000 operations per sec - \$200)
	First Email Demo
	Concepts Evaluation Model
	First USAF Helicopter Simulation
	AMSWAG
	LCMS (Log Capability Measurement System)
	ATARI Founded and ships "PONG"
	C Prolog
	Air Force Establishes Red Flag
	Mil-Std-1558 (Defacto 6-Post Motion System Standard)
	CATTS (Combined Arms Tactical Training System)
	DIVWAG
	First Electronic Calculator (TI)
	Packet Networking Developed
	Intel 8080
	Computer Aided Operations Research Facility – Kings Point
	Two Networked Full Motion Wide FOV Flight Simulations
	ARI Report on Tactical Engagement Simulation (TES)
	DIVLES
	Cope Thunder Exercise (TI)
	Gates & Allen Form MicroSoft
	First Ethernet At Xerox
	Simulator Fidelity Studies (Beginning with motion/Without motion)
	AFHRL
	AIMVAL/ACEVAL Test
	MINI-3 (LLNL)
	VECTOR
	TACSM (Artillery)
	Jobs & Wozniak Form Apple and Produce Apple 1
	TRS-80
	NATO Reference Mobility Model
	Initial Concept for Large Scale Distributed Simulator Networking
	CIG Dome (VTRS)
	PTOS (Patriot Air Defense Simulation)
	ART BASS Studies
	AFOTEC uses simulation to identify T&E issues and extrapolate results
	JANUS (LLNL)
	TAC BRAWLER Development Begins
	TRS-80 Calculates Battle Damage at Naval War College
	"War in Europe" Game
	Reforger '79 driven by manual game "battle"
	Motorola 68000
	DEC 11/780

	Intel 8086
	Table Top Gunnery Trainer
1980 thru 1990	AMRAAM Test (four linked simulations)
	First Class Cockpit Simulator (CAE Link8767 & MD80)
	Army National Training Center (NTC)
	First PC based Constructive Simulation (Wang 2000)
	VIGS (Video Disc Based Gunnery)
	Tank Driver Simulator
	Navy Mobile Sea Ranges
	IBM PC
	Hayes Smart Modem 200
	Common Lisp
	Four Low Cost Tank Gunnery Trainers Networked
	VCASS Helmet Mounted Display
	ARPA Video Arcade Tank Gunnery Trainer (\$.25 per play)
	Mission Training Plans
	JANUS delivered to Army
	Silicon Graphics Formed
	Geometry Engine (SGI)
	SUN I
	CRAY XMP
	Postscript
	TCP/IP Adopted
	ADA
	Lotus 123
	Delta Graphics Founded
	Warrior Preparation Center Established
	CAMMS (Munition in a minicomputer)
	ACA Buy (Urban Game)
	Casteforem Development
	ARPA SIMNET – Concept Validation Study
	MODSIM (Modular design for simulations)
	Compuscene III with Texture (GE)
	Air Force Established Blue Flag
	JANUS 4.0
	“Fire in the East” Board Game
	Apple Eye (Intervisibility on a microcomputer)
	VPL Founded (Jason Lanier)
	MAC 128
	ARPANET Split – MILNET Added (Later DDN)
	1,000 Most Computers on the net
	Apple Laserwriter
	Motorola 68020
	FATS Founded

	EOSAEL
	B1-B Engineering Research Simulation
	IPFN Testbed (ALBQ) netted to PTOS simulation (El Paso) via T1
	JRTC Development and Demo
	Navy Fallon Tactical Aircrew Combat Trainer System (TACTS)
	METT-CAP Mission Planner
	JESS
	VIC (Vector in Commander)
	CBS Development Begins
	Battle Command Training Program (BCTP) established using JESS
	Delta Graphics acquired by BBN
	Motorola 68030
	NSFNET Created
	PERL
	Intel 80386
	JANUS TRAC
	SEES 1.0 (LLNL)
	Air Force Red Flag measurement and debrief system
	CMTC Opens
	IRIS 4D70G with MIPS R2000 (First Unix RISC workstation (SGI)
	TAC Evaluation of Limited FOV Visual (F15)
	Semi-Automated Forces (SAF) Development Begins
	First Networked Simulations – Ft. Knox
	First Z Buffered Low Cost Multi-Channel CIG (Delta Graphics)
	Multigen 1.0
	SIMNET-D
	SIMNET Graphics Engine (Delta Graphics)
	Compuscene PT 2000 (GE)
	OPTEC FOG-M Comparative Test
	MS Excel
	C++ 2.0 (multiple inheritance)
	10,000 Most Computers on the Net
	“Morris Worm” Attacks 7,000 of 60,000 Most computers on the Net
	NSF Backbone to T1 (1.5 MB/sec)
	ViewPoint Data Labs Founded
	Strategic Defense Simulation and Performance Assessment
	Brave Shield “88 – First JWC Distributed CBS Exercise
	EADSIM Development Begins
	First Formal User Test of SIMNET (Ft. Knox to Hood) 60 Netted Simulations
	Distributed Interactive Simulation (DIS) Workshops Begin
	First Long Haul Training Exercise (Ft. Knox to Rucker)
	SIMNET Testbed, 250 Simulations, 11 Sites
1990 thru 1995	BFIT (SIMNET to Naval Ship)

	VP 1000 First PC Based CIG (TSI)
	Extended Air Defense Test Bed (EADTB) Begins
	Multiship R&D Testbed
	Marksmanship Trainers at 100 locations (USMC)
	British Army Approves Simulation Strategy
	Crossbow SA-12 Digital Simulation Prototype
	Simulation Policy Study (OSD/FMP/TRF)
	ARPANET Transitioned (Ceases)
	Visual Basic
	Sun Sparc 2
	DMSO Established
	Maritime ITEM Development Begins
	First Aggregate Level Simulation Protocol (ALSP) Demo
	JCM (LLNL/JWC)
	JMASS Established
	Unit Performance Assessment System (UPAS)
	RADSIM 1.0 (Low Cost Radar Simulation)
	CD ROM Map Libraries
	SIMNET SAF 6.1
	NPSNET
	Mobile SIMNET (ANG)
	First DIS 1.0 Demon (TSI)
	Close Combat Tactical Trainer (CCTT) ASARC
	Battlefield Distributed Simulation (BDS-D) and Advanced Distributed Simulation Tactical (ADST-I)
	ALSP ULCHI Focus Lens Europe-US-Korea
	First Executive Council Modeling and Simulation (EXCIMS) meeting
	MIPS R4000 64 Bit RISC
	NSFNET BackBone to T3 (45 MB/sec)
	GOPHER ( University of Minnesota)
	BICM (Battlefield Intel Collection Model)
	Defense Science Board (DSB) Report on Advanced Distributed Simulation (ADS)
	World Wide Web (WWW) application (CERN)
	STRICOM Established
	CSSTSS Development Begins
	Reforger '92 First Simulation Driven FTX
	ALSP Program Funded
	JCM/SOFNET (LLNL/JWFC AF/DMSO)
	SEES (Security Exercise Evaluation System)
	Marksmanship Trainer On Board (USMC)
	First C-17 ATS
	Compuscene VI Target Generation (GE)
	MODSAF
	VRLink Ships

	SIMNET to CSRDF
	CCTT AWARD
	IITSEC Exhibit Floor "On the Net"
	Warbreaker
	Joint Precision Strike Demonstration (JPSD)
	SGI Reality Engine
	First Onyx (SGI)
	Topscene on Aircraft Carrier
	Automated Training analysis and Feedback System (ATAFS)
	Simulation Training Integrated Performance Evaluation System (STRIPES)
	JMASS 1.0
	Core Battle Simulation (CBS) STAARS
	Joint WarFighting Center(JWFC) Standup
	BCBST (Battle Command and Brigade Staff Trainer) (BBS and JANUS)
	Simulation Demo to SASC
	Intel 60 MHZ Pentium
	1,000,000 Host Computers on the NET
	MOSAIC "Surf the NET"
	WWW Worms, Crawlers, Snakes, Spiders collect information around the WEB
	Motorola Power PC 601
	Martin Marietta Buys GE Aerospace
	Loral Buys BBN Sim + Quintron
	AF/XOM Established
	GPS Based Ranges
	AFRES (Multi-Task Trainer Low Cost F-16 unit level)
	USAF Visual System Evaluation
	Synthetic Theater of War (STOW)
	ADS Architecture Study
	ZERO Regard
	CFOR CSSIL
	MDT2 Multi Service Distributed Trainer Testbed
	DIS Protocol 1.0 Approved (IEEE 1278)
	INCOMMS '94 First Demo of Dismounted unit (virtual) netted to brigade (constructive) – Ft.Benning
	TACCSF
	First DIS Voice communications (TSI)
	A2ATD (Air Defense and Armor)
	TADSIM (Theater wide DIS R&D)
	Infoscope (TSI)
	JCOS
	Leathernet (USMC)
	Zealous Pursuit

	IPORT 1.0 (Unicycle)
	High Level Architecture (HLA)/Architecture Management Group (AMG)
	STOW – Europe
	MAIS-DIS Compliancy Demo
	MORS ORSA Handbook
	MORS SimVal Symposium
	Joint ADS JT&E (JADS) – T&E Evaluation
	JCM/SIMNET (STRICOM)
	Atlantic Resolve
	JTLS 1.85 (First Joint Multi-sided Simulation)
	BIDS
	Loral Buys IBM Federal Systems
	MAC Power PC
	DEC Alpha 300 Mhz
	GPS Full IOC
	Netscape IPO
	7,000,000 Host computers & 61,000 Networks on the NET
	VRML
	Windows '95
	Lockheed and Martin Marietta Merge
	DMSTTIAC Established
	DoD M&S Master Plan
	BIDS (LUT/DPG/UT)
	NTF Wargame
	Roving Sands
	JWID '95
	Kernel Blitz
	JPSD '95
	Prairie Warrior
	MOBA Digital Data (Benning & Quantico)
	MILES 2000
	Small Arms Naval Trainer
	HLA Protofederations
	IPORT 2.0 (Treadmil)
	BBS-MODSAF
	ADST-II

Table 1. M&S and Contributing World Technology Events after (Thorpe, 1995)

## **APPENDIX B. SIMULATION BASED ACQUISITION (SBA) “CHEAT SHEET”**

Tasking: Lt Gen Martin suggested that SARDA develop a “cheat sheet” that he and other decision-makers can use to ask program managers the “right questions.” The purpose of this is two-fold: first, to educate the decision makers on what the philosophy of SBA actually means when it comes to implementing it on programs, and second, to cause the program managers to “answer the question before its asked” (as Lt Gen Martin said) and in effect, start implementing SBA on their programs in the process of preparing to answer the questions. Following are (1) general modeling and simulation questions, and (2) SBA - specific modeling and simulation questions.

### **A. GENERAL M&S QUESTIONS**

#### **1. M&S Planning**

- IS THERE A PLAN FOR M&S USE ACROSS THE SYSTEM LIFECYCLE?
- IS THE M&S STRATEGIC PLAN INCLUDED IN THE ACQUISITION STRATEGY DOCUMENT? IS IT UPDATED ANNUALLY?
- IS THE PLAN FUNDED?
- DOES THE PLAN TAKE INTO CONSIDERATION:
  - IDENTIFICATION OF ALL MODEL AND SIMULATIONS
  - THE SOURCE OF NEEDED DATA FOR THE MODELS AND SIMULATIONS
  - REUSE ACROSS ACQUISITION PHASES?
  - VV&A?
- USE OF MODELS IN SOURCE SELECTION AND THEIR RELEASE TO INDUSTRY?
- IS THE USE OF M&S ACCOUNTED FOR IN THE TEMP?

#### **2. Requirements**

- WHAT MODELS/SIMS AND DATA WERE USED, IF ANY, AS PART OF THE AOA TO GENERATE REQUIREMENTS? WERE THEY VERIFIED, VALIDATED AND ACCREDITED?

#### **3. Cost**

- DOES THE FUNDING PROFILE SUPPORT THE ROBUST USE OF M&S THROUGHOUT THE PROGRAMS LIFECYCLE? (E.G., FRONT-LOADED?)
- DOES THE USE OF M&S MAKE THE PROGRAM MORE AFFORDABLE? IF SO, IN WHAT WAY?
- COST AVOIDANCE
- COST SAVINGS

- SCHEDULE SAVINGS
- OTHER

#### **4. Contractor Incentives**

- ARE THE PROPER INCENTIVES IN PLACE FOR THE CONTRACTOR TO USE A DIGITAL ENVIRONMENT TO CONTAIN COSTS?

### **B. SBA-SPECIFIC QUESTIONS**

SBA is a new acquisition strategy that exploits recent advances in M&S technologies. It involves not only changes in the technologies and environment, it also involves changes in the culture and processes. The following questions seek evidence of those changes.

SBA enables a more iterative acquisition process versus the traditional serial process of moving through the phases. We conceive, design, manufacture, test, train, operate & sustain (in an iterative nature) concurrently in the virtual world before locking in on a solution. We delay locking in our requirements (ORD) until we examine the trade space in a virtual system of systems environment. As the system is developed and produced, the representation of the new system continues to be matured in parallel with that development. In terms of implementation, this process should be reflected, in part, in the program acquisition strategy in a section entitled “M&S approach”:

#### **1. Shared Digital Environment - SBA Concepts That Apply**

- Collaborative Environments – Simply put, this is 2 or more programs collaborating together on a given problem and sharing and reusing models/sims. Example: missile PM collaborating with aircraft and ship PMs for a strike warfare collaborative environment; or, several aircraft PMs collaborating across the aircraft product line
- QUESTION: IS THE PROGRAM PARTICIPATING IN ANY COLLABORATIVE ENVIRONMENTS?
- Distributed Product Description or DPD (e.g., virtual representation of the system including all the associated information that makes it “smart” such as the function of the system, special manufacturing requirement, cost of system, etc. a DPD is a step beyond a virtual prototype)
- QUESTION: DOES THE ACQUISITION STRATEGY CALL FOR DEVELOPMENT OF A DPD? IF SO, WILL THE GOVERNMENT OWN THE RIGHTS? IS IT PLANNED TO EVOLVE THE DPD OVER THE LIFE OF THE PROGRAM?
- DoD/Industry Resource Repository or DIRR – A shared repository for dpds as well as other models and simulations to enable government and industry sharing and reuse. It is an extension of the existing DoD modeling and simulation resource repository (MSRR). Access controls required - example: Boeing may have a Boeing-proprietary



DPD of the JSF that only Boeing and the government can access (but not Lockheed). JSF may also use a "purple DPD" that anyone can access.

- QUESTION: DOES THE ACQUISITION STRATEGY CALL FOR PLACEMENT OF THE DPD IN THE MSRR (FUTURE -DIRR)? HAVE APPROPRIATE ACCESS CONTROLS/PROPRIETARY DATA RIGHTS ISSUES BEEN RESOLVED?
- Ultimately, when SBA is implemented as a strategy, programs, working in conjunction with each other, will use common standards and adopt a common architecture which will facilitate interoperability and reuse supporting DoD goals of reduction in cycle time and cost.
- QUESTION: HOW IS THE PROGRAM WORKING TO LEVERAGE EXISTING STANDARDS (E.G., HLA)?
- QUESTION: HOW ARE YOU USING STANDARDS TO ENSURE INTEROPERABILITY WITH OTHERS OUTSIDE YOUR PROGRAM?
- QUESTION: WHAT M&S ARE YOU LEVERAGING FROM OTHER PROGRAMS?
- QUESTION: WHAT PARTNERSHIPS HAVE YOU INITIATED/INTEND TO SUSTAIN TO BOTH CONTRIBUTE TO THE COMMUNITY AND REDUCE DEPARTMENT ACQUISITION COSTS?

## **2. Simulation Test and Evaluation Process (STEP)**

- STEP is an integral part of the SBA strategy. The STEP Guidelines, signed by Dr. Sanders and Mr. Coyle, require an evaluation strategy integrating test and evaluation (T&E) with M&S.
- QUESTION: DOES YOUR PROGRAM HAVE AN INTEGRATED T&E AND M&S STRATEGY?
- QUESTION: TO WHAT EXTENT IS YOUR EVALUATION STRATEGY IMPLEMENTING THE STEP GUIDELINES?
- QUESTION: STEP REQUIRES EARLY INPUT FROM THE TEST COMMUNITY AS PART OF THE ACQUISITION LIFE CYCLE. AS PART OF YOUR EVALUATION STRATEGY, AT WHAT POINT DO THE TESTERS BECOME INVOLVED IN YOUR PROGRAM?
- QUESTION: WILL OT USE M&S FOR IOT&E?

### **3. Evolved Process**

- Integrated Product And Process Development (IPPD) and the use of Integrated Product Teams (IPTs) with empowered government and industry members to accomplish defined tasks are critical to take advantage of the technological advances which make SBA possible.
- QUESTION: HAS THE PROGRAM FORMED GOVERNMENT/INDUSTRY IPTS, INCLUDING ONE FOR M&S, WITH EMPOWERED GOVERNMENT AND INDUSTRY MEMBERS TO ACCOMPLISH THE DEFINED TASKS THAT ARE CRITICAL TO TAKE ADVANTAGE OF THE TECHNOLOGICAL ADVANCES WHICH MAKE SBA POSSIBLE?

### **4. Evolved Culture**

- Incentives are required for development in the initial stages of a program to develop the integrated data environment and other infrastructure and resources for SBA.
- QUESTION: HAS THE PROGRAM MANAGER PROVIDED INCENTIVES FOR INDUSTRY TO EITHER ASSIST IN OR DEVELOP THE NECESSARY PRODUCTS AND SERVICES FOR SBA TO BE IMPLEMENTED AS A STRATEGY?
- The process must build a partnership between government and industry. The first opportunity of this is during the request for proposals and proposal evaluation
- QUESTION: DOES THE ACQUISITION STRATEGY CALL FOR THE SHARING OF MODELS & SIMULATIONS EARLY ON (ALA IPPD), TO INCLUDE DURING SOURCE SELECTION, AND DURING THE LIFE OF THE PROGRAM?

(SARDA, 2000)

## **APPENDIX C. COST FACTOR DEFINITIONS**

### **A. COMMUNICATIONS – NONRECURRING**

Total nonrecurring expenditure of communications equipment and services to make the fully configured and installed system operable at its inception. Include in this category data communications equipment, such as modems and data encryption devices, as well as other communications costs, such as local area networks.

### **B. COMMUNICATIONS – RECURRING**

Yearly payments for communications costs. Include in this category data communications equipment, such as modems and data encryption devices, as well as other communications costs, such as local area networks.

### **C. CONTRACTING**

Total expenditure of contracts for construction, design, development, consulting, and installation of system.

### **D. CONVERSION COSTS**

For replacement or upgrade systems, the incremental costs incurred only from the costs to convert hardware (such as PCs, mainframes, disk drives, servers, printers) or software (such as database, batch programs, and expert systems) from one system to another. These costs are only incurred if the system under consideration is replacing another specific system. Examples are batch transfer programs, data re-entry, hardware modification.

### **E. EQUIPMENT**

Yearly costs allocated for the purchase, lease or rental of other equipment to support business operations excluding equipment associated with the new system.

**F. EQUIPMENT – OTHER**

Yearly costs allocated for the purchase, lease or rental of other equipment to support the use of the system. Include in this category photocopiers, file cabinets, fire safes, microfiche, optical storage facilities and other office products.

**G. FACILITY SPACE OCCUPANCY**

Yearly payments for allocated rents and building user costs for business operations other than the space allocated to the new system (excludes utilities).

**H. HARDWARE – NONRECURRING**

Total dollar expenditure, by year, of hardware to make the fully configured and installed system operable at its design inception. Include in this category mainframes, desktop, laptop, PCs, disk drives, tape drives, display monitors, keyboards, printers and other peripheral equipment. This does not include possible conversion costs for upgrading from older systems.

**I. HARDWARE LEASE OR RENTAL – RECURRING**

Yearly payments for system hardware lease or rental. Include in this category mainframes, desktop, laptop, PCs, disk drives, tape drives, display monitors, keyboards, printers and other peripheral equipment.

**J. INCIDENTALS**

Other minor costs associated with day to day business operations. Exclude incidental costs associated with the new system.

**K. INTERAGENCY**

Yearly payments to (less credits received from) other agencies for shared facilities used and services other than systems operations.

**L. MAINTENANCE**

Yearly payments for maintenance of business operations. Exclude from this category all repairs, maintenance, and emergency service support costs directly attributable to the system.

**M. PARALLEL OPERATIONS**

Expenditure needed for parallel operations or systems testing on a nonrecurring basis.

**N. PERSONNEL SALARIES AND FRINGE**

Yearly allocated costs for personnel who perform Benefits functions to be supported by the new system. This should include all organizational units and sites whose operations will change as a result of the system.

**O. RESIDUAL VALUE**

The salvage value of the entire system at the conclusion of its life cycle.

**P. SECURITY**

Yearly costs to provide system security and integrity. Include in this category security monitoring systems, alarm systems, camera and voice recording and storage systems, lock and pass key systems, and security personnel costs.

**Q. SOFTWARE – NONRECURRING**

Total dollar expenditure of software to make the fully configured and installed system operable at its inception. Include in this category all system software packages, off-the-shelf software, and custom software, site or network license and all original software programming and development costs. Important: do not include software conversion or upgrade costs here; instead, include these in conversion costs.

**R. SOFTWARE LEASE OR RENTAL – RECURRING**

Yearly payments for system software lease or rental. Include in this category all system software packages, off-the-shelf software, and custom software, site or network license, and all original software maintenance costs.

**S. STUDIES**

Total expenditure for studies necessary to implement this system alternative.

**T. SUPPLIES**

Yearly payments for supplies to operations other than those associated with the new system.

**U. SYSTEM TESTING AND BACKUP**

Recurring costs to test reliability and integrity of system in operation, including costs for memory back up. This does not include costs for nonrecurring start-up and installation testing.

**V. TRAINING**

Recurring training costs associated with routine business operations, e.g., training aimed at improving supervisory skills. Exclude costs for training associated with the new system.

**W. TRAVEL**

Yearly travel expenses incurred in the normal course of business operations. Exclude any travel costs that are associated with the new system. Include train, bus, taxi, and airline tickets, gas, mileage and toll charges and auto rental expenses.

**X. USEFUL SYSTEM LIFE**

Forecast of the planned useful system life from the first month of system implementation.

**Y. UTILITIES**

Yearly payments for costs of utilities allocated to business operations other than the new system.

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## APPENDIX D. DOCUMENTATION CHECKLIST

DOCUMENTATION CHECKLIST	
<p><input type="checkbox"/> <b>ALTERNATIVES ANALYSIS:</b></p> <ul style="list-style-type: none"> <li>• Answer the <i>Three Pesky Questions</i>.</li> </ul> <p>1) Does the investment in a major capital asset support core/priority mission functions that need to be performed by the Federal Government?</p> <p>2) Does the investment need to be undertaken by the requesting agency because no alternative private sector or government source can better support the function?</p> <p>3) Does the investment support work processes that have been simplified or otherwise redesigned to reduce cost, improve effectiveness, and make maximum use of commercial, off-the-self technology?</p> <p><input type="checkbox"/> <b>PROJECT PLAN:</b></p> <ul style="list-style-type: none"> <li>• Major milestones with schedule</li> <li>• Deliverables</li> <li>• Critical path decision points</li> <li>• Resources</li> <li>• Integrated Project Team</li> </ul> <p><input type="checkbox"/> <b>ACQUISITION PLAN – PART ONE:</b></p> <ul style="list-style-type: none"> <li>• Statement of need</li> <li>• Significant conditions affecting acquisition</li> <li>• Capability or performance</li> <li>• Tradeoffs</li> <li>• Risks</li> <li>• Modular contracting</li> </ul> <p><input type="checkbox"/> <b>BASELINE ASSESSMENT AND STATEMENT OF NEED:</b></p> <ul style="list-style-type: none"> <li>• Baseline assessment criteria</li> <li>• Functionality</li> <li>• Full life cycle cost</li> <li>• Expected funding levels cost</li> <li>• Security Plan</li> <li>• Capacity to manage asset</li> <li>• Existing resource baseline</li> <li>• Performance gap</li> </ul>	<p><input type="checkbox"/> <b>BENEFITS COST ANALYSIS (BCA):</b></p> <ul style="list-style-type: none"> <li>• Assumptions and constraints</li> <li>• Alternatives and their schedule, costs, and benefits</li> <li>• Risk and sensitivity analysis</li> <li>• Performance goals and measures for monitoring the project</li> </ul> <p><input type="checkbox"/> <b>FEASIBILITY ANALYSIS AND MARKET RESEARCH:</b></p> <ul style="list-style-type: none"> <li>• Feasibility:               <ul style="list-style-type: none"> <li>• Availability</li> <li>• Affordable</li> <li>• Cost &amp; Benefits</li> </ul> </li> <li>• Market Research:               <ul style="list-style-type: none"> <li>• Availability of commercial items to meet the need, and whether they require modification</li> <li>• Distribution and support capabilities of suppliers</li> </ul> </li> </ul> <p><input type="checkbox"/> <b>FUNCTIONAL REQUIREMENTS ANALYSIS:</b></p> <ul style="list-style-type: none"> <li>• Performance criteria, goal, or ultimate output</li> <li>• Definition of the common uses of the IT investment</li> <li>• Ranking of each requirement in order of importance</li> <li>• Decomposition of functional requirements into self-contained features</li> <li>• Requirements should be described in terms of:               <ul style="list-style-type: none"> <li>• Business outcome</li> <li>• Purpose</li> <li>• S/SO program components involved</li> <li>• Operating constraints</li> <li>• Mission</li> <li>• Capability</li> <li>• Schedule and cost objectives</li> </ul> </li> </ul> <p><input type="checkbox"/> <b>QA PLAN:</b></p> <ul style="list-style-type: none"> <li>• Life cycle process</li> <li>• Periodic independent review</li> </ul> <p><input type="checkbox"/> <b>RISK MANAGEMENT PLAN:</b></p> <ul style="list-style-type: none"> <li>• Risks including costs, schedule and technical</li> <li>• Potential risks</li> </ul>

Figure 6. Document Checklist from (GSA, 2000)

DOCUMENTATION CHECKLIST (CONT.)	
<p><input type="checkbox"/> <b>SECURITY PLAN:</b></p> <ul style="list-style-type: none"> <li>• Government information protected from misuse, loss and unauthorized access</li> <li>• Security responsibilities assigned</li> <li>• Systems security plan reviewed by security specialist</li> <li>• Rules of the system</li> <li>• Training issues</li> <li>• Incident response capabilities</li> <li>• Interconnectivity security addressed</li> <li>• Security controls reviewed</li> </ul> <p><input type="checkbox"/> <b>ACQUISITION PLAN - PART TWO:</b></p> <ul style="list-style-type: none"> <li>• Source of supply</li> <li>• Competition description</li> <li>• Source selection procurement</li> <li>• Contracting consideration</li> <li>• Budgeting and funding</li> <li>• Product description</li> <li>• Priorities</li> <li>• Contractor vs. Government preference</li> <li>• Performance Management System</li> <li>• Test and evaluation</li> <li>• Logistics considerations</li> <li>• Indicate Government furnished property</li> <li>• Indicate Government furnished information</li> </ul> <p><input type="checkbox"/> <b>PLANS FOR ASSETS / IT INVESTMENTS:</b></p> <ul style="list-style-type: none"> <li>• Operational analysis</li> <li>• Steady State Plan</li> <li>• Schedule Post Implementation Review</li> <li>• Asset Disposal Plan</li> </ul>	<p><input type="checkbox"/> <b>DISASTER/RECOVERY AND CONTINGENCY PLAN:</b></p> <ul style="list-style-type: none"> <li>• Strategy for mission performance and recovery from loss of existing support</li> <li>• Plans for continuous testing of the system</li> </ul> <p><input type="checkbox"/> <b>POST IMPLEMENTATION REVIEW:</b></p> <ul style="list-style-type: none"> <li>• System reviewed and documented on a regular basis</li> <li>• PIR conducted by an independent evaluation team</li> <li>• Customer user satisfaction reviewed</li> <li>• Internal business reviewed</li> <li>• Strategic impact and effectiveness reviewed</li> <li>• Innovation reviewed</li> </ul>

Figure 7. Document Checklist Continued from (GSA, 2000)

## APPENDIX E. PROJECT RISKS CHECKLIST

### PROJECT RISKS CHECKLIST

- ☐ **Strategic Risk**
  - Alignment with the agency's overall business strategy
  - Clarity of expression of anticipated project outcomes.
  - Presence of metrics to verify the successful completion of each project phase.
- ☐ **Financial Risk**
  - Size of expenditure required.
  - Existence of cost/benefit analysis.
  - Existence of defined payback and time frame of payback.
  - Reputation and financial status of vendor(s).
- ☐ **Project Management Risk**
  - Experience of project management teams
  - Existence of work plan for entire life cycle.
  - Degree of development of measurable milestones.
  - Length of time for project implementation.
  - Existence of system for tracking unresolved issues.
  - Definition of user and development skill requirements.
- ☐ **Technology Risk**
  - Plan for validating that user needs are met.
  - Existence of load test in accordance with industry standards
  - Evaluation of technology options.
  - Maintainability and ability to upgrade key technologies.
  - Vendor's ability to implement technology.
- ☐ **Security Risk**
  - Perform risk assessment.
  - Implement security controls.
  - Security training and awareness.
  - Contingency planning & disaster recovery.
  - Comply with security policy.
- ☐ **Change Management/Operational Risk**
  - Development of acceptance plan.
  - Experience and ability of existing staff to support new system.
  - Organization's familiarity with proposed hardware/software environment.
  - Development of system operating procedures.
  - Impact to organization of system failure.
  - Magnitude of change introduced by system.
  - Number of business units impacted.

Figure 8. Risk Checklist from (GSA, 2000)

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